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Development of a Wastewater Treatment Plant (WWTP) Sludge (Biosolids) Management Strategy

West Point U.S. Military Academy, NY

by
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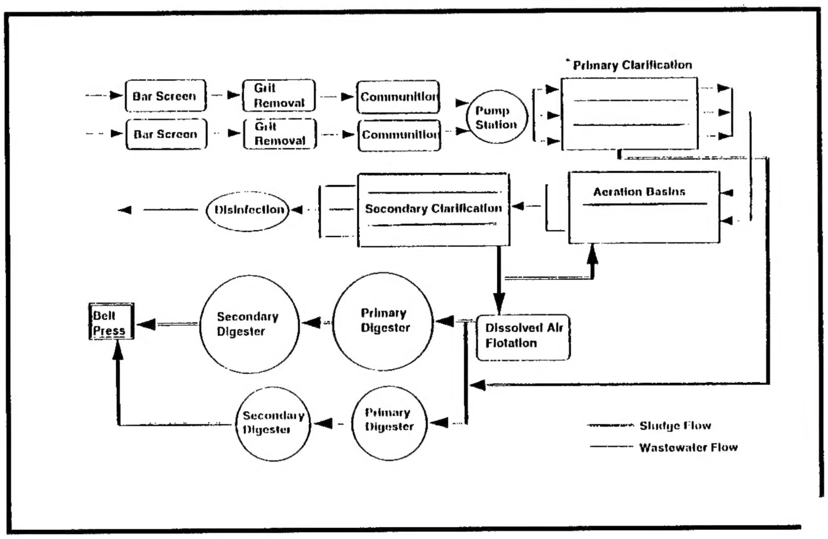

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This study developed a strategy to manage Target Hill WWTP sludge more effectively. Factors governing strategy development were: compliance with the USEPA's new Part 503 regulations, economy, and simplicity of operation. Sludge should be stabilized, and stabilized biosolids should be beneficially used as a soil supplement to avoid landfill disposal. The study recommended composting Target Hill WWTP sludge at the Rockland County Solid Waste Management Authority central composting facility currently under construction, and reusing the biosolids as a soil amendment at West Point Military Academy. By implementing this recommendation, Target Hill WWTP will be able to save Operations and Maintenance (O&M) money and to serve as a model installation for Federal and local government cooperation in biosolids management.

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Foreword

This study was conducted for the U.S. Military Academy, West Point, NY, Military Interdepartmental Purchase Request (MIPR) No. 5FCHA50067; Work Unit U65, "Biosolids Sludge Management at West Point, NY." The technical monitors were Donald Michand and Jason Kim, MAEN-UFD.

The work was performed by the Industrial Operations Division (UL-I) of the Utilities and Industrial Operations Laboratory (UL), U.S. Army Construction Engineering Research Laboratories (USACERL). At the time of this study, Richard Shanley was an Environmental Engineer with USACERL, but is now associated with John Carollo Engineers, Portland, OR. Special appreciation is owed to Dennis Dugan, Chief Operator at West Point, for valuable technical input. The USACERL principal investigator was Dr. Byung J. Kim. Chang W. Sohn is Acting Chief, CECER-UL-I; Martin J. Savoie is Acting Operations Chief, CECER-UL; and Gary W. Schanche is the responsible Technical Director, CECER-UL. The USACERL technical editor was William J. Wolfe, Technical Resources.

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1 Introduction

Background

Effective sludge management can be a difficult task for wastewater treatment plant (WWTP) operators. As sludge regulations become more stringent, and as more landfills are closed down, many WWTPs are consequently forced to develop new and more effective residual management plans. Solids residual management is a global environmental problem with local solutions. While it may appear that each nation takes a different approach for residual management, in reality, individual WWTPs have unique combinations of environmental conditions and regulatory requirements. The best solution for solids residual problems may vary by location, and even by individual WWTP. Key factors affecting the success of good residual management for a WWTP include, but are not limited to:

- the regulatory framework and attitude of government
- available technologies and "know-how"
- economical feasibility and available resources
- public awareness and acceptance.

The U.S. Military Academy (USMA) at West Point, NY, currently operates a domestic WWTP, the Target Hill Wastewater Treatment Facility. As with many small WWTPs, the sludge generated at USMA is ultimately disposed by landfill. The moisture content of sludge must be significantly reduced before it can be landfilled. The WWTPs currently use mechanical dewatering via a belt filter press to achieve an average 13 percent solids content, an amount significantly below the landfilling requirement of 20 percent solids for sludge required in the New York Codified Rules and Regulations (NYCRR), Part 360. To meet this standard, USMA's sludge is mixed with sand before transport, a practice that places an unnecessary burden on the treatment facility in terms of both labor and materials. Instead of decreasing the transportation cost and landfilling burden by reducing the volume of sludge through an effective sludge management system, the facility meets state mandates by actually increasing

the amount of sludge requiring ultimate disposal. In reality, biosolids should not be disposed as waste at all; rather, biosolids from WWTPs can and should be beneficially used. This study undertook a technical evaluation of feasible alternatives to sludge management to remedy the disposal problems at USMA, with a primary focus on sludge/biosolids management technologies and appropriate consideration of regulatory aspects, economics, public acceptance, and current biosolid management trends.

Objectives

The objectives of this study were:

1. To assess technical alternatives to current methods of solids residual management at West Point Military Academy

2. To recommend an improved sludge management method for implementation at the USMA WWTP

3. To provide guidance on beneficial use of biosolids at that installation.

Approach

1. An extensive literature search was done to review commercially available technologies to improve dewatering and/or ultimate use and disposal of WWTP solids residuals. Appropriate vendors of feasible technology were contacted. Included here is a summary of conventional and emerging technologies* for thickening, stabilization (especially stabilization processes that meet the pathogen reduction and vector attraction reduction requirements), conditioning, dewatering, and beneficial use. Special attention is given to the reed bed dewatering system, which has been shown in a case study for Fort Campbell WWTP (Appendix A to this report) to economically dewater and stabilize sludge for small WWTPs.

2. Other municipal WWTPs were visited to review effective, currently employed sludge management strategies. Four municipal WWTPs and the New York State Department of Environmental Conservation were visited to collect technical and regulatory data. The Rockland County Solid Waste Management Authority was contacted to evaluate the potential use of the Rockland County central composting facility, which will become operational in 1998.

3. The unit operations at the WWTP that generate, treat, and affect the ultimate use of disposal of the sludge were reviewed.

4. Critical operating and design parameters related to sludge treatment were defined to assess the possibility of improving existing operations.

5. Alternatives for beneficial use of West Point biosolids were analyzed.

6. Sludge was characterized to ensure compliance of the requirements for beneficial use as soil amendment at West Point Military Academy. Bench scale tests were conducted to assess the performance of the existing belt filter press.

7. Preliminary cost and design information on the most attractive alternatives were compiled. Because some attractive solutions (such as composting) will require substantial capital investment, both interim and long-term strategies were devised.

Scope

Although this study was done to resolve West Point Military Academy sludge problems, the information derived from this work may form a baseline guidance to resolve similar solids residual problems at other Department of Defense installations.

Mode of Technology Transfer

It is anticipated that the results of this study will be incorporated directly into the sludge management processes at the West Point WWTP. It is recommended that the sludge (biosolids) from that facility be composted at the Rockland County's central sludge composting facility, that the composted biosolids be used as soil amendment at West Point Military Academy, and that other technologies summarized in this report be gradually tested and adapted to improve sludge management at West Point.

Product and Manufacturer Information

Any discussion of specific products, product manufacturers, or any views or opinions expressed herein are solely those of the author and do not represent either the views or policies of any agency of the federal government, including the U.S. Army or the U.S. Army Corps of Engineers, Construction Engineering Research Laboratories.

Metric Conversion Factors

The following metric conversion table lists conversion factors for U.S. standard units of measure used throughout this report.

1 in.	=	25.4 mm
1 ft	=	0.305 m
1 sq ft	=	0.093 m2
1 cu ft	=	0.028 m3
1 mi	=	1.6•1 km
1 lb	=	0.453 kg
1 gal	=	3.78 L
1 psi	=	6.89 kPa
1 µm	=	1x10-6m
lb/sq ft	=	4.882 kg/m2

2 WWTP Description

Sludge Related Operations

Figure 1 shows a schematic diagram of the USMA WWTP. The rated design capacity of the plant is 2.06 million gallons per day (MGD), but the average flow from January to September 1996 was 1.89 MGD. Influent wastewater is primarily characterized by biochemical oxygen demand (BOD) and total suspended solids (TSS), which average 145mg/L and 106 mg/L, respectively. The flow and wastewater characteristics are based on figures reported in an "Operator Assistance Program" report (ES Environmental Services 1988). The permit limits on BOD and TSS are a daily average of 30 mg/L (weekly maximum) and 45 mg/L (monthly maximum) for both.

Residuals generated from domestic wastewater treatment plants often include grit, screenings, scum, and sludges. (Note that this report uses the term "residual" interchangeably with the terms "sludge" or "biosolids," but with a slightly different connotation.) As Figure 1 shows, sludge is generated in the primary settling tanks and in the activated sludge system. Primary sedimentation tanks are used at the WWTP to remove readily settleable solids and floating material, thereby reducing the suspended solids content. Properly designed sedimentation tanks typically remove 50 to 70 percent of the suspended solids and 25 to 40 percent of the influent BOD_5. A previous study indicated that the loading on primary clarifiers were within typical design parameters at the rated flow rate of 2.06 MGD.

The activated sludge process follows primary treatment to remove carbonaceous organic matter (defined by BOD). To maintain an adequate concentration of organisms, a portion of the settled solids for the secondary clarifiers is returned to the aeration tanks. The removal of excess activated sludge, referred to as waste activated sludge (WAS), comprises the other major portion of sludge produced. Note that various properties of the WAS make it the most difficult to dewater, as compared to other biological sludges and primary sludge.

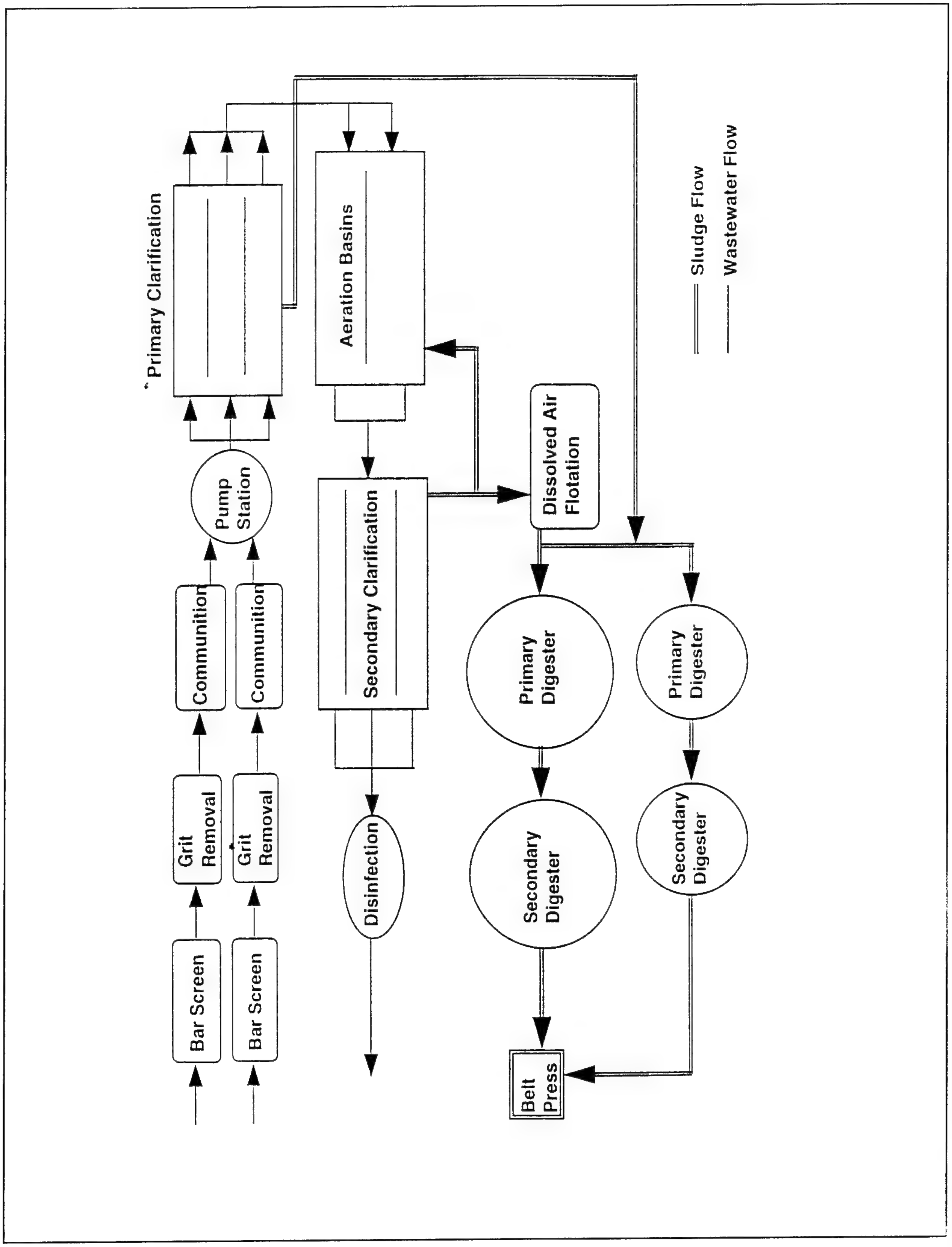

Figure 1. Target Hill WWTP schematic.

Sludge Generation and Disposal Data

Thickening is used to increase the solids content of the sludge before it is stabilized in the digesters. At the Target Field WWTP, only the WAS is thickened, via processing in a dissolved air flotation (DAF) unit. The volume reduction achieved by thickening is beneficial to subsequent treatment processes, including digestion and dewatering, because it effectively increases the capacity of tanks and equipment, reduces the amount of chemicals required for sludge conditioning (e.g., polymers for dewatering), and reduces the amount of heat the digesters require.

For example, if a typical WAS at 0.8 percent solids is thickened with DAF to 4 percent solids, a fivefold decrease in the sludge volume is realized. The thickened WAS and primary sludge are eventually combined in the anaerobic digestion process. As with other stabilization processes, anaerobic digestion is used to reduce pathogens, eliminate offensive odors, and eliminate the potential for putrefaction. Two-stage digestion is used at the Target Field WWTP. The sludge is mixed and heated in the primary digester, where the biological reduction of the volatile (organic) matter principally takes place. After primary digestion, the sludge is sent to the secondary digester. The second tank stores and concentrates the digested sludge. The extent to which the sludge is digested greatly affects its subsequent dewaterability and potential end uses. The most critical design parameters to determine the design capacity are the mean cell residence time (MCRT) and volumetric loading factors. Overall digester performance is characterized by the destruction of volatile suspended solids (VSS), which are used to quantify the degradable fraction of the sludge.

Table 1 shows sludge generation data compiled by West Point WWTP operators. The sludge generation volumes included sludge, polymers, and sand. The sludge from that filter press contained 13 to 15 percent dry solids. Sand with about 10 percent of sludge weight was added to elevate the sludge solids content of 20 percent.

An earlier feasibility study for land application of West Point sludge done (U.S. Army Environmental Hygiene Agency 1990) recommended that West Point not land apply its sludge for economic reasons. The report assumed a generation quantity of 225 tons/ year (dry weight). Chapter 4 of this report gives an actual cost comparison among other technical alternatives.

Table 1. 1993 sludge generation data at the West Point WWTP.

	Year		
Month	1993	1994	1995
Jan	140	100	20
Feb	140	140	100
Mar	160	160	260
Apr	180	180	260
May	240	200	200
Jun	60	60	80
Jul	80	160	200
Aug	200	200	160
Sep	200	180	200
Oct	100	180	200
Nov	100	180	180
Dec	140	140	40
Total	1,8401	840	1,880
* (Unit: Disposal volume in cubic yard)			

Sludge Management in the Region

The West Point Military Academy is located in Orange County, New York. The New York State Department of Environmental Conservation (NYSDEC) Region 3 Office is the responsible State Regulatory agency. The Region 3 Office covers Orange, Rockland, Westchester, Dutchess, Putnam, Sullivan, and Ulster Counties. It is of interest to analyze NYSDEC Region 3 sludge data (NYSDEC,1994). From 1 September 1992 to 31 August 1993, NYSDEC Region 3 generated a total of 37,356 dry tons of sludge. Of this quantity, 64 percent was landfilled (23,900 dry tons) at NYS landfills (9,498 dry tons) and out-of-state landfills (14,402 dry tons), 32 percent was incinerated (11,929 dry tons), and only 3 percent (972 dry tons) was processed for beneficial use. The percentage of beneficial use in Region 3 is much lower than in other regions (e.g., Region 7, which processes 82 percent of its waste for beneficial reuse). The three WWTPs that processes sludge for beneficial use in the NYSDEC Region 3, were visited during this study:

1. Tri-municipal, Dutchess County, which uses aerated static pile composting; POC: Mr. Peter Witko, tel. 914/297-5750

2. Saugerties, Ulster County, which uses alkaline stabilization, specifically the N-Viro method; POC: Mr. Gregory Teetsel, tel. 914/246-2331

3. Yorktown Heights, Westchester County, which uses windrow composting; POC: Mr. Daniel Ciarcia, tel. 914/962-5722.

A common problem at these facilities was the limited demand for stabilized biosolids. Tri-municipal WWTP produced an excellent quality of biosolids. However, because of the limited demand for biosolids, a large quantity of composted biosolids were disposed at Al Turi landfill as waste. New York State required a permit for beneficial use of biosolids, which the contracted landfill did not have. Therefore, composted biosolids could not be used as landfill cover. The Saugerties WWTP had a similarly difficult time finding biosolids users in the region.

In NYSDEC Region 3, eight landfills were in operation in 1994; only Al Turi Landfill is in operation in 1996. In a telephone conversation (7 February 1996), Mr. Gambino, the owner of Al Turi landfill, said that Al Turi landfill would accept waste for 3 more years under the existing permit based on 4,000 ton per week disposal rate. The landfill has applied for a permit to extend the life of landfill for an additional 8 years, and the owner predicts that the landfill will be in operation for additional 10 years at the current disposal rate.

In NYSDEC Region 3, Orange county does not have any specific sludge management plan, Westchester County appears to favor incineration as a sludge treatment method, and Rockland County plans to build a central composting facility to accommodate sludge generated in the County. Chapter 4 of this report discusses the Rockland county composting facility plan and composting process in more detail.

3 Regulatory Framework for Part 503

History and Related Regulations

Although manure and sludge have been used for farming for a long time, the scientific evaluation of sludge use is relatively recent. Rudolfs (1928) determined the fertilizer value of various sludges at different wastewater treatment plants. Five decades later, the Federal Water Pollution Control Amendments of 1972 recognized land application of sludges as an alternative method for sludge disposal and recognized a need for land application research. The U.S. Environmental Protection Agency (USEPA 1979a) implemented land application criteria including pH and cadmium application rate and PCB concentrations. In 1984, the USEPA issued its "Policy on Municipal Sludge Management," which actively promoted the beneficial use of sludge while maintaining and improving environmental quality and protecting public health. The beneficial use of sludge provides twofold benefits: (1) it saves landfill space and reduces liability from landfill, incineration, and ocean dumping, and (2) improves soil properties and reduces the use of chemical fertilizers as soil amendment or organic fertilizer.

The USEPA (1989) released its draft of proposed sewage sludge regulations (Part 503), known to be the most comprehensive, technically based sludge regulations to date. It is also a controversial USEPA regulation, which has attracted some 3,000 pages of public comments. The USEPA added additional scientific findings, the results of the *Second National Sludge Survey*, and extensive public comments to the revision of the Part 503, and finally implemented the substantially revised Part 503 regulations, effective March 1993. The final Part 503 encourages beneficial use of sludge.

A comment in Bastian's (1992) draft 503 regulations is worth repeating:

> Regulation of sewage sludge management and disposal is a journey and not a destination. It is an ongoing process that must be dynamic, to account for new scientific information as it is continuously generated, and to adapt to changing practices that are being constantly innovated. Above all, the regulatory process must maintain a balanced perspective

> that considers the potential threat of sludge-borne contaminants to public health and the environment based on the best scientific data available, but also considers practical constraints, which may be fiscal, political, [or] technological [issues] faced by municipalities that generate the sludge.

Residual management strategy is greatly affected by different federal policies, laws, and regulations. In addition to 503 regulations, the regulations applied to sludge use and disposal include:

- *Marine Protection, Research and Sanctuaries Act*, which bans ocean dumping of sludge.
- *Toxic Substance Control Act*, which requires PCB-containing sludge to be disposed of in a hazardous waste incinerator, a chemical waste landfill, or an EPA-approved alternative method.
- *Clean Air Act Ambient Air Quality Standards, New Source Performance Standards*, and *National Emissions Standards for Hazardous Air Pollutants,* which apply to the operation of sludge incinerators and dryers.
- *Resource Conservation and Recovery Act*, which considers a sludge with hazardous characteristics as hazardous waste, and regulates landfill and land application.
- *Clean Water Act*, which requires the USEPA to identify all major sludge use and disposal methods. The USEPA established the Part 503 rule to meet these requirements.
- *National Environmental Policy Act*, which may require an Environmental impact statement for sludge facilities that significantly affect the environment.
- *Comprehensive Environmental Response, Compensation, Liability Act* and *Superfund Amendments and Reauthorization Act*, which is applicable to clean-up of sludge containing hazardous substances and to the release of information to the public.

Overview of Part 503

In the spring of 1993, the USEPA regulations for the use and disposal of sewage sludge were adopted under 40 CFR Part 503. These regulations are now commonly referred to as "Part 503." Part 503 establishes specific requirements for sludge that is applied to land for beneficial purposes, placed on a surface disposal site for final disposal, or fired in a sewage sludge incinerator. The requirements are applicable to generators, preparers, and appliers of sewage

sludge. The generator of the biosolids is generally a WWTP, which may or may not be the preparer and applier. For example, an off-site composting facility accepting sludge from a WWTP would also be a "preparer." Note that, if the WWTP is *not* the preparer, then even if the biosolids are eventually land applied, its requirements regarding Part 503 are greatly reduced.

Since these regulations are only expected to impact Army facilities using beneficial land application for final disposal, incineration and surface disposal are also addressed in this study. Included in land application requirements are general requirements: pollutant limits; management practices; operational standards; and monitoring, reporting, and recordkeeping requirements. It is important to realize that all of these standards may or may not be applicable, depending on the determined quality and amount of sludge produced. For example, if a WWTP prepares an "exceptional quality" sludge, the general requirements and management practices of 503 are waived. The advantages of reducing regulatory requirements by preparing a higher quality sludge will be highlighted in the subsequent discussion of Part 503.

Pollutant Limits

Part 503 requires all land-applied biosolids to meet standards for 10 heavy metal pollutants. Because most Army WWTPs are not significantly impacted by industrial operations, sludges from these sources should have low metals concentrations. Table 2 defines the pollutant limits for the metals in the units of milligrams per kilogram on a *dry weight basis*. Note that analysis and reporting of the metals in the incorrect units (e.g., mg/L) is a common and easily avoided mistake in achieving Part 503 compliance.

All land-applied biosolids must meet ceiling concentration limits. If any one of the ceiling limits is exceeded, the biosolids are not acceptable for land application. Note that it is acceptable to dilute a sludge with material to meet the limits, but this should only be used as an emergency measure. In addition to meeting the ceiling limits, biosolids applied to the land must also meet *one* of the other heavy metals requirements shown in Table 2: pollutant concentration limits, cumulative pollutant loading limits, or annual pollutant loading limits.

In addition to limits on heavy metals, land applied biosolids are regulated with regard to pathogen (disease-causing organisms) contamination and vector (e.g., flies and mosquitoes) attraction reduction. The level of pathogen destruction defines the sludge as either "Class A," which is virtually pathogen free, or "Class B," which has realized a great reduction in pathogen content, but requires that site restrictions be imposed to allow the natural decomposition of the remaining

Table 2. Pollutant limits.

Pollutant	Ceiling Concentration for all Biosolids (mg/kg)	Pollutant Concentration for PC biosolids (mg/kg)	Cumulative Pollutant Loading Rate (kg/hectare)	Cumulative Pollutant Loading Rate (kg/hectare)	Annual Pollutant Loading Rate Limits (kg per hectare per year)
Arsenic	75	41	41	41	2.0
Cadmium	85	39	39	39	1.9
Chromium	3000	1200	3000	3000	150
Copper	4300	1500	1500	1500	75
Lead	840	300	300	300	15
Mercury	57	17	17	17	0.85
Molybdenum	75	—	—	—	—
Nickel	420	420	420	420	21
Selenium	100	36	100	100	5.0
Zinc	7500	2800	2800	2800	140
Applies to:	All biosolids land applied	Bulked and Bagged Biosolids	Bulk biosolids	Bulk biosolids	Bagged biosolids
From 503:	Table 1, 503.13	Table 3, 503.13	Table 2, 503.13	Table 2, 503.13	Table 4, 503.13 (USEPA, 1994)

pathogens before human contact is made. The alternatives for meeting the Class A and Class B pathogen destruction requirements follows:

Class A. All Class A biosolids must meet a fecal coliform limit *or* a density of *Salmonella sp.* bacteria when the biosolids are used or disposed, prepared for bagged distribution, or prepared to meet the exceptional quality criteria. In addition, *one* of the six alternatives listed below must be met:

- *Alternative 1 for Thermally Treated Biosolids*, in which biosolids must be subjected to one of four time-temperature regimes.
- *Alternative 2 for Biosolids Treated in High Temperature-High pH Process*, in which biosolids must meet specific pH, temperature, and air drying requirements.
- *Alternative 3 for Biosolids Treated in Other Processes*, in which the preparer must demonstrate that the process can reduce enteric viruses and viable helminth ova. After such demonstration, the operating conditions must be maintained.
- *Alternative 4 for Biosolids Treated in Unknown Process*, in which biosolids must be tested for pathogens—*Salmonella sp.*, or fecal coliform bacteria, enteric viruses, and viable helminth ova—at the time the biosolids are used or disposed, or prepared for sale or give-away. Demonstration of the process is unnecessary.
- *Alternative 5 for Use of a Process To Further Reduce Pathogens (PFRP)*, in which biosolids are treated in one of the recognized PFRPs under the defined operating

conditions. Currently used PFRPs include composting, heat drying, heat treatment, and thermophilic aerobic digestion.

- *Alternative 6 for Use of Process Equivalent to PFRP*, which includes treatment in a process deemed equivalent to a PFRP by the permitting authority.

Class B. One of the three requirements must be met to meet the Class B requirement:

1. *For Monitoring of Indicator Organisms*, testing for fecal coliform density as an indicator of pathogens at time of use or disposal.

2. *For Biosolids Treated in a Process To Significantly Reduce Pathogens (PSRP)*, biosolids must be treated by one of the recognized PSRPs under the defined operating conditions. PSRPs include aerobic digestion, air drying, anaerobic digestion, composting, and lime stabilization.

3. *For Treating Biosolids in a Process Equivalent to a PSRP*, treatment in a process deemed equivalent to a PSRP by the permitting authority.

Because Class B biosolids still contain some pathogens, site restrictions are imposed on the area subject to land application. The combination of a Class B standard with the site restrictions is considered equally protective of public health as a Class A sludge. A more detailed discussion on pathogen reduction requirements is available in: *40 CFR 503, Control of Pathogens and Vector Attraction in Sewage Sludge, A Plain English Guide on the EPA Part 503 Biosolids Rule, and Sewage Sludge (Biosolids) Management Manual for Army Facilities* (Army Environmental Center).

Vector Attraction Reduction

A requirement for reducing vector attraction reduction (VAR) is necessary to lower the potential transmittal of pathogens. Part 503 contains 10 options for meeting the VAR requirement for regarding land application. Options 1 through 8 reduce the attractiveness of the sludge to the vectors, while options 9 and 10 prevent contact of the sludge with vectors:

- *Option 1*: Reduce the mass of volatile solids by 38 percent or more via sludge treatment. For example, from influent of sludge to digester at time of disposal, a greater than 38 percent loss of VSS is measured.

- *Options 2 and 3*: Demonstrate VAR with additional anaerobic digestion or aerobic digestion in laboratory unit. Even if Option 1 is not met, it may be possible that adequate VAR has been achieved, but that biological degradation has taken place prior to the stabilization process and a 38 percent VSS reduction

is not possible. Adequate VAR can be demonstrated in a bench scale unit by digesting the sludge for a given time and documenting that less than 17 percent additional loss of VSS takes place.

- *Option 4*: Be equal to or less than the maximum specific oxygen uptake rate (SOUR) for aerobically digested sludge.
- *Option 5*: Aerobic process at greater than 40 °C. This is most suitable for composting, and is achieved by maintaining the minimum temperature for at least 14 days.
- *Option 6*: Addition of alkaline material under specified conditions.
- *Option 7*: Dry biosolids without unstabilized solids to a minimum of 75 percent solids.
- *Option 8*: Dry biosolids with unstabilized solids to a minimum of 90 percent solids.
- *Option 9*: Inject biosolids beneath soil surface.
- *Option 10*: Incorporate biosolids beneath soil surface (e.g., by plowing).

Meeting the Land Application Requirements

The preceding land application requirements are collectively used to define which of the four options for meeting Part 503 is met. The four land application options, listed in order of increasing regulatory requirements, are:

1. The Exceptional Quality (EQ) option
2. The Pollutant Concentration (PC) option
3. The Cumulative Pollutant Loading Rate (CPLR) Option
4. The Annual Pollution Loading Rate (APLR) Option.

Note that all four options are equally protective of public health, by inclusion of additional management practices, site restrictions, and general requirements.

Biosolids meeting the EQ option must meet the ceiling concentration and pollutant concentration limits for the metals shown in Table 2. For a sludge to meet the EQ option, it must meet the Class A pathogen destruction requirement, and one of the first eight VAR options. Currently, EQ biosolids are

primarily achieved via composting and heat drying. The great benefit to generating EQ sludge is that all the land application general requirements and management practices are waived. EQ biosolids can be applied in either bulk or bagged form in as free a manner as any commercially available soil conditioner. Monitoring, recordkeeping, and reporting requirements must still be met.

To meet the pollutant concentration option, the same metals requirement must be met as for EQ biosolids. However, PC biosolids fall under Class B with respect to pathogen destruction. Therefore, Part 503 site restrictions, general requirements, and management practices apply. Any one of the previously defined VAR options must also be met. A Class A sludge is also considered PC type if it meets VAR option 9 or 10. PC sludge may only be distributed in bulk form, and cannot be applied to lawns or home gardens since site restrictions are required. Most sludges generated at WWTPs will fall under into the PC category.

The CPLR option is available to sludges that meet the ceiling limits, but not the pollutant concentration requirements for metals. In this case, safe application of the sludge is ensured by applying sludge under the specified loading rates shown in Table 2. The CPLR sludges may meet either the Class A or B Standards, and any of the 10 VAR requirements. Any applicable site restrictions, requirements, and management practices must be met. The disadvantage to applying a CPLR sludge is that documentation of previous cumulative metals loading since July 1993 must be provided, site description must be established, and the cumulative amount of pollutant applied must be tracked and documented to ensure that metal loading limits are not exceeded. When the CPLR is reached at a site, biosolids subject to CPLR limits cannot be applied anymore. However, EQ biosolids may still be applied after the CPLR is reached. CPLR biosolids are only applied in bulk, and cannot be used on home lawns or gardens since the cumulative loading cannot be tracked in those places.

The annual pollutant loading rate designation is applicable only to sludge that is sold or given away in bag or container. The metal pollutant limits are met through the ceiling limits and APLR limits in Table 2. As with EQ sludge, the biosolids must be Class A and must meet one of the first eight VARs. APLR sludge may be applied on any type of land, but is generally used in lawns and home gardens. APLRs are used in place of CPLRs because it is not feasible to track the cumulative loading with bagged sludges applied for home use.

All types of sludge are required to meet general requirements and management practices, with the exception of the EQ biosolids. For PC and CPLR biosolids, the preparer must provide information to the applier of the biosolids needed to

comply with the Part 503 requirements. Some limited information must also be provided by a generator to a party that further processes the biosolids (e.g., a composting facility), but it is not required by Part 503 to provide metal removal or pathogen destruction data. The preparer must provide notification of the total nitrogen concentration for the biosolids to the applier, to ensure that they are applied at an agronomic rate. The applier must also gather information necessary to comply with 503. For CPLR biosolids, the applier must notify the permitting authority of the application site, obtain records (if available) for any previous applier, landowner, or permitting authority that defines the amount of CPLR pollutant applied since July 1993, and keep records of the additional amount of pollutant applied.

Requirements governing land application management practices state that PC and CPLR biosolids cannot be applied to flooded, frozen, or snow-covered land in a manner that allows their entry into a wetland or other water of the United States. Application of biosolids may not in any way threaten endangered species. If PC or CPLR biosolids are applied to agricultural land, forests, or public contact sites, they may not be applied at a rate greater than the agronomic rate for nitrogen. This is to ensure that nitrate contamination is avoided. For APLR biosolids, a label must be affixed to the bag or other container with the following information: name and address of preparer of biosolids, statement prohibiting application not in accordance with label instructions, the AWSAR, and the nitrogen content.

For any of the types of sludge land applied, Part 503 requires monitoring, recordkeeping, and reporting requirements for both the preparer of the biosolids and the applier. For EQ biosolids, there are no requirements for the applier. The frequency of monitoring of pollutants, pathogen densities, and VAR depend on the amount of biosolids generated (Table 3).

Table 3. Frequency of monitoring requirements.

	Biosolids Amount (metric ton/ yr)	Biosolids Amount (English tons)	Frequency
Ave. per day per 365 days less than 290	>0 to <0.85	> 0 to <320	Once per year
Equal or greater than 209 but less than 1500	0.85 to <4.5	320 to <1650	Once per quarter (4 timer per year)
Equal or greater than 1500 but less than 15,000	4.5 to <45	1650 to 16,500	Once per 60 days (6 times per year)
Equal or greater than 15,000	45	16,500	Once per month

Summary

A typical Army troop installation WWTP will meet both the ceiling concentration and pollutant concentration limits for the regulated metals. Generally, technology has not been implemented at Army WWTP that will enable the production of a Class A sludge. Therefore, assuming that the stabilization process (usually digestion) is operating satisfactorily, a PC sludge will be available for land application. As discussed, land application of a PC sludge requires that all of the applicable site restrictions, management practices, and general requirements be met. The site restrictions involve harvesting restrictions for food crops, restrictions on animal grazing, and turf growing. Also, public access to sites where Class B sludge applied is restricted for 1 year for land with a high potential for public exposure (e.g., parks), and for 30 days for land with a low potential for access.

If PC limits are met, the avoidance of the requirement of tracking the pollutant loading greatly reduces the recordkeeping burden. The overall frequency of monitoring requirement will be quite low (one to four times per year), considering that a typical Army WWTP generally produce less than 4.5 dry tons per day of biosolids. However, it is recommended that any facility operating a beneficial application program monitor more frequently than once or twice per year.

Current Assessment of Part 503 at West Point

The Target Hill WWTP is minimally impacted by industrial wastewaters, and therefore, there is little likelihood that sludge from this source will contain a significant concentration of metal pollutants. This was verified by testing reported in a past AEHA land treatability study done for West Point, and by USACERL data gathered for this study. Table 4 lists the results of this testing along with Part 503 and New York Department of Environmental Conservation Standards (AEHA 1990). Appendix B summarizes the USACERL data. The reported concentrations reflect an average of four samples, but even the maximum sample concentration for each metal was well below its Part 503 requirement. The results indicate that West Point biosolids meet the highest 503 standards with respect to metals. This greatly reduces the burden of land application because there is no requirement to track and record the quantity of metals applied or determine the amount applied to the desired site in the past.

Table 4. Target field sludge analysis.

Pollutant	Dewatered Sludge (mg/kg)	PC Limits (mg/kg)	Ceiling Limits (mg/kg)	NYDEC Limits (mg/kg)
Arsenic	2.5	41	75	—
Cadmium	2	39	85	25
Chromium	23.8	1200	3000	1000
Copper	398	1500	4300	1000
Lead	61	300	840	1000
Mercury	1.1	75	57	10
Molybdenum	<5	—	75	—
Nickel	11.3	420	420	200
Selenium	2.2	36	100	—
Zinc	572	2800	7500	2500 (AEHA, 1990)

In addition to meeting a metals requirement, the sludge must also demonstrate pathogen and vector attraction reduction. The current treatment used at the WWTP with anaerobic digestion and mechanical dewatering would likely result in a Class B sludge, that is to say, the sludge produced at Target Hill could not currently meet Class A requirements unless modified. Recalling the previous discussion of Part 503, the applicable site restrictions, general requirements, and management practices would still apply.

Of the different alternatives to fulfill the Class B standards, the simplest and cheapest for West Point would be treatment by a Process to Significantly Reduce Pathogens (PSRP). This can be achieved via existing anaerobic digestion, provided that minimum specific mean cell residence time (MCRT) is met for specific temperatures. Part 503 requires that the MCRT and temperature be maintained for 15 days at 35 to 55 °C and for 60 days at 20 °C. According to the study from the Operator Assistance Program done at West Point, the primary anaerobic digester has a design MCRT of 28 days at a flow rate of 2.07 MGD (ES Environmental Services 1987). Assuming that the digester heating equipment is operating properly, the system will meet the PSRP requirements for anaerobic digestion. However, it is critical that the MCRT be defined for the actual sludge loading rate and that the operating temperature be determined to verify this.

The most likely alternative to demonstrate vector attraction with the existing sludge treatment system at West Point is to meet the 38 percent reduction of volatile suspended solids (VSS). Generally, properly operating anaerobic digesters have little difficulty in meeting this standard. Four typical methods for determining the VSS reduction in the sludge treatment process are:

1. Full mass balance equation

2. Approximate mass balance equation

3. "Constant ash" equation

4. Van Kleeck equation.

The details of the use of the equations with examples are also presented in *Control of Pathogens and Vector Attraction in Sewage Sludge* (USEPA 1992). Additionally, if beneficial practice is implemented, the VAR requirement may be met by preventing vectors from contacting the biosolids by using Option 9 or 10.

Any beneficially applied sludge must meet the monitoring, recordkeeping, and applicable reporting requirements for land-applied sludge. Assuming a total production of 290 tons (263 metric tons), the minimum required frequency of monitoring of once per year is required (Table 3). However, continuous monitoring of PSRP parameters, such as temperature, is necessary to meet Part 503 requirements. Recordkeeping and reporting of these parameters are also required for West Point. If the sludge is defined as PC, which is likely to be the current case, the applier of the biosolids has a responsibility for keeping records that certify and describe how management practices and site restrictions (for Class B) are met. If additional technology is implemented to generate an EQ sludge, the applier has virtually no responsibility for its application through Part 503, although it would be strongly encouraged to apply the sludge at an agronomic rate.

4 Biosolids Management Alternatives Related to Target Hill WWTP

Sludge management consists of a few major steps, including: thickening, stabilization, conditioning, dewatering, and beneficial use or disposal. These steps should be compatible with each other, and the overall system management should be integrated to minimize total costs. This chapter briefly summarizes emerging technologies for biosolids management in comparison with conventional technologies, and will recommend strategies to improve Target Hill WWTP sludge management.

Thickening

The objective of thickening, conditioning, and dewatering is to separate water from solids. The purpose of stabilization and other sludge processes are to reduce volume, odors, pathogens, and putrescibility of the sludge so that biosolids can be beneficially used or effectively disposed. Thickening reduces the water content of sludge resulting in the reduced amount of sludge to be treated and disposed of. Sludge can be thickened before stabilization or dewatering. Conventional thickening methods include the use of gravity, dissolved air floatation, centrifuges, and gravity belts.

Both basket and disc centrifuges are being phased out of operation for centrifuge thickening in the United States. Solid bowl centrifuges have been effective in thickening operations with or without the use of polymers, and are in widespread use today. Chemical costs are minimized with centrifugal thickening, since polymers are usually not required for thickening the solids to 6 percent by weight. Some manufacturers for centrifuges include: Bird Machine Co. (South Walpole, MA, tel. (508) 668-6855; Clinton Separators, Inc. (Clinton Separators Inc. (Warminster, PA, tel. (215) 672-7872; Humboldt Decanter Inc., Norcross, GA, tel. (770) 564-7300; Centrico, Inc., Northvale, NJ, tel. (201) 767-3900; Alfa Laval Shaples, Inc., Warminster, PA, tel. (215) 443-4000.

Emerging thickening technologies include the rotary drum, rotary biosolids thickener, and Sirex Pulse Power thickeners (EPRI 1995). A rotary drum thickener consists of a solids conditioning unit and media-covered drums. In the

drum, filtrate passes through the porous media and the solids are conveyed through the drums. The porous media used in rotary drums include wedgewire, stainless steel fabrics, and polyester fabrics. Most applications for rotary drum thickeners are for waste-activated sludge thickening. Due to the many associated operational and mechanical problems, there have been limited uses for thickening biosolids. A rotary biosolids thickener is a relatively new technology; data on the rotary biosolids thickener is still limited. The flocculated solids are introduced into the thickener where they are uniformly mixed by a variable speed, flat-bladed impeller turning just fast enough to maintain the spiral delivery to the discharge. The manufacturer of this technology is Thickener Technologies, Inc. Sirex Pulse Power thickener enhances particle agglomeration and settling by imparting specific frequency pulse to the solids with the aid of a special paddle system operating in the center of the settling tank. The solids are reportedly thickened to a concentration of 12 percent. This technology has been used in France. The manufacturer is Sirex Pulse Hydraulic systems, Inc.

Stabilization

Conventional stabilization processes include anaerobic digestion, aerobic digestion, lime stabilization, conventional drying, and composting. Emerging stabilization processes include autothermal thermophilic digestion, alkaline stabilization, and use of new sludge dryers (WEF 1995a).

Anaerobic Digestion

Target Hill WWTP uses anaerobic digestion for sludge stabilization. Anaerobic digestion of sludge is a solubilization and reduction process of organic substances in absence of oxygen. Three distinct groups of micro-organisms perform different functions:

1. Extracellular enzymes hydrolyze complex organics (e.g., carbohydrates, proteins, and lipids) to soluble organics (glucose, amino acids, and fatty acids).
2. The acids producers convert soluble organics to short-chain organic acids (e.g., acetic, propionic, and lactic acids)
3. The methane formers convert the short-chain organic acids to methane, carbon dioxide, and other trace gases.

The micro-organisms responsible for the step (1) and (2) are often called "acids formers." In comparison with acids formers, methane formers are more

sensitive to environmental changes such as pH, temperature, and substrate compositions, and grow more slowly. Therefore, operators have to closely monitor the methane formers' activity. Once methane formers are not active, acids formers would generate more acids, causing the pH to drop further, resulting in reduction of methane formers population.

Many researchers have studied sludge anaerobic digestion to improve the process efficiencies. In the 1950s, heating and mixing were combined to make a high rate anaerobic digester. Most anaerobic digesters are operated in the mesophilic range, however, they can be operated in the thermophilic temperature range. Thermophilic digestion may offer several advantages over mesophilic digestion, including increased reaction rates, increased destruction of pathogens, and better dewatering characteristics. On the other hand, limitations of the process include extreme sensitivity of micro-organisms, high energy requirements, and more offensive odor from the digested sludge. Since Part 503 did not give credit to thermophilic digestion for the potentially greater reduction in pathogens, selection of a thermophilic digestion should be carefully evaluated for the claimed advantage. A relatively new configuration for anaerobic digestion is the egg-shaped digester, which has been extensively used in Europe. The egg-shaped digester helps to eliminate grit buildup problem (Stukenburg et al. 1990). A two-stage anaerobic digestion divides the functions of fermentation and solids-liquid separation into two separate tanks in series. By contrast, two-phase anaerobic digestion separates the acid formation phase from the methane formation phase. Based on a bench scale study (Ghosh et al. 1975), full scale facilities (Ghosh et al. 1991) were built. The claimed advantages of two phase system include higher rates of volatile solids reduction, increased higher quality methane production rates, higher pathogen reduction, and elimination of the problem of foaming.

Anaerobic digestion typically produces class B biosolids, which are suitable for restricted beneficial reuse on land (USEPA 1993). Anaerobic digestion substantially reduces pathogen concentration but is not sufficient to meet Class A biosolids requirements. The data in Table 5 (WEF 1995a p 57) show that anaerobic digestion reduces detectable viruses and fecal coliform by one to four orders of magnitude, with the higher reductions at thermophilic operating ranges. However, some helminth ova survive even after thermophilic digestion.

Aerobic Digestion

Aerobic digestion of sludge destroys degradable organic components and reduces pathogens by a suspended growth biological process. The advantages of aerobic digestion over anaerobic digestion include the production of a biologically stable

product and the use of simpler controls. However, disadvantages include a high energy cost associated with oxygen transfer. Recent development of highly efficient oxygen transfer equipment and research in operation at elevated temperatures may address this concern. Aerobic digestion processes actually entail two steps: the direct oxidation of biodegradable matter and endogeneous respiration. In the endogeneous respiration step, the predominant reaction in aerobic digestion, the cell mass of micro-organisms is converted to carbon dioxide and water as follows:

$$C_5H_7NO_2 + 7O_2 \rightarrow 5CO_2 + 3H_2O + NO_{3^-} + H^+ + \text{Energy}$$

As a result, pH drops and temperatures rise during aerobic digestion. It may be possible to solve the problem of excessively depressed pH by periodic denitrification or by the addition of lime. Denitrification could be accomplished by periodically turning off the aerators while continuing to mix the digester if the facility is designed with a draft tube aerator containing an air sparger (WEF 1995a, p15). Limited information on the sequential treatment of sludge is available. An aerobic digester in elevated temperature will be further discussed in the autothermal thermophilic aerobic digestion.

Alkaline Stabilization

Lime stabilization is a simple and cost-effective process. At a pH of 12 or more with sufficient contact time, pathogens and micro-organisms are either inactivated or destroyed. Lime stabilization greatly reduces pathogens and

Table 5. Typical pathogen concentrations with anaerobic digestion.

	Concentration, number/100 mL	
Pathogen	**Raw sludge**	**Digested sludge**
Virus (various)	*380 - 7x10^4*	*BDL - 10^3*
Bacteria		
Total coliforms	4.3x10^9 - 5x10^9	3x10^4 - 7x10^7
Fecal coliforms	1.4x10^9 -10^9	BDL -7.8x10^6
Salmonella	3 - 4.6x10^4	3 - 62
Streptococcus fecalis	2.3x107 - 1.5x10^8	BDL - 2.2x10^6
Mmycobacterium tuberculosis	10^7	10^6
E Coli	9.5x10^7	BDL
Parasites		
Ascaris	200 - 10^4	0 - 10^3
Helminth eggs	20 - 700	30 - 70
Tapeworm eggs	2x10^3	2

BDL: Below detection limits
Source: Farell et al., 1986; Ghosh et al., 1991; Kun et al., 1989; Stukenburg et al, 1992; and USEPA, 1979b.

odors. However, lime does not destroy the organics that promote the growth of biological organisms. Failure to dose the sludge to a pH of 12 or more for a few hours can lead to a drop in pH during storage so that subsequent odor problems and possible regrowth of pathogenic organisms may occur (USEPA 1979).

Generally, lime stabilization generates a large quantity of sludge. Iron, aluminum salts, or polymers are often used to improve dewaterability and add sludge volume. Although lime stabilization meets Class B requirements of Part 503 regulations, land application of lime-stabilized sludge is not appropriate where the soils are alkaline. Lime stabilization is often chosen in the following situations (Lue-Hing C. et al. 1992):

- stabilization facilities at small WWTPs
- backup for existing stabilization facilities
- interim sludge handling
- expansion of existing facilities to improve odor and pathogen control.

Lime stabilization can be part of a sludge conditioning process before dewatering (pre-lime stabilization) or following a dewatering step (post-lime stabilization). The primary factors used to design a pre- or post-lime stabilization system are pH, contact time, and lime dosage. Many researchers have studied these factors for reliable stabilization. It is agreed that a significant reduction in pathogens and odors occurs when pH is increased to 12.5 for 30 minutes (which keeps pH above 12 for 2 hours). Westphal and Christensen (1983) reported minimum lime dose of 25 to 40 percent as $Ca(OH)_2$ for pre-lime stabilization prior to vacuum filtration and 25 to 30 percent for effective post-lime stabilization.

Advanced alkaline stabilization can meet Class A requirements of Part 503 regulations. Most of the advanced alkaline stabilization processes are proprietary. Additional chemicals other than lime include cement kiln dust, lime kiln dust, Portland cement, or fly ash. Some examples of the advanced alkaline stabilization processes follow (Lue-hing et al. 1992):

- The RDP company has a patent on the envessel pasteurization process. In this process, dewatered sludge is preheated in an insulated and electrically heated screw conveyor. The heated sludge and quick lime are mixed in a heated and insulated pug mill mixer. Because of supplemental heat, alkaline material must be added to elevate pH. The mixture is conveyed to a heated and insulated vessel reactor where it is retained at a minimum

temperature of 70 °C for 30 minutes to meet PFRP requirements of sludge disposal regulations.

- Bio Gro Systems uses the exothermic reaction of quick lime with water to meet the pasteurization requirements of a minimum temperature of 70 °C for 30 minutes.

- The N-Viro process is a patented system that can meet PFRP requirements. Technically, the process is defined as an "advanced alkaline stabilization with subsequent accelerated drying." More than 30 N-Viro systems are in operation (personal discussion with N-Viro International Corp.). Two alternative methods of conducting the N-Viro process have been approved by the USEPA as a PFRP equivalent process. In the first process, alkaline materials are added to and mixed with the sludge in sufficient quantity to achieve a pH of 12.0 or greater for at least 7 days. For example, Burnham et al (1992) used 35 percent kiln dust and small amount of quicklime. Following mixing, the alkaline-stabilized sludge is dried for at least 30 days until a minimum solids concentration of at least 65 percent is achieved. In the second process, a pH greater than 12.0 is maintained for at least 72 hours. Concurrent with maintaining this high pH, the sludge is heated to a temperature for at least 53 °C and is maintained at that temperature for at least 12 hours.

Ammonia odors are most typically encountered at alkaline stabilization facilities. The elevated pH resulting from the addition of alkaline materials causes the dissolved ammonia in the liquid to be released as a gas. (If adequate ventilation is not provided, operators may need to wear respirators.) Odor-control systems can be chosen, from a simple enhanced ventilation and a single scrubber to a three-stage system, packed tower/mist scrubber/packed tower. The latter system may use sulfuric acid, sodium hypochlorite, and sodium hydroxide to neutralize and oxidize the odor-causing compounds (WEF 1995a).

In NYSDEC Region 3, Saugerties WWTP used the N-Viro process to produce Class A biosolids. The application of N-Viro system to Target Hill WWTP was considered. N-Viro Preliminary design and cost data provided by International Corporation's New York Distribution Office follow. Facilities and equipment for 1 dry ton per day system include:

- 21,000 cu ft silos
- 60 x 175-ft covered translucent for curing
- 20 x 60-ft covered building for mixer and conveyor

- skid steer loader/Auger
- dump truck
- conveyors.

Estimated costs are about $400K (including engineering and contingency).

The N-Viro system appears to be highly cost effective. However, potential specific problems associated with alkaline stabilization process at West Point include:

1. In accordance with Mr. Bob Jones, an agronomist at DPW, West Point, West Point soil is generally alkaline. Therefore, alkaline soil amendment is not desirable.
2. The West Point Military Academy is a historically preserved site. The chance of receiving a permit to construct silos for N-Viro systems to store lime and cement kiln dust is slim.
3. West Point Military Academy attracts many tourists. Ammonia odor has to be completely controlled.

Composting

Composting is an aerobic sludge stabilization process. The heat generated from biochemical reactions destroy pathogens and the humus-like end product can be used as soil amendment meeting "Class A" requirements of Part 503 regulations. In composting, where temperatures reach the thermophilic range, practically all viral, bacterial, and parasitic pathogens are eliminated (WEF 1995a, p110).

Historically, composting has been more of an art than a science. About 50 years ago, several mechanical composting systems were introduced in Europe. The static pile method was introduced by USDA in 1970s. Many advances were made in composting based on this early work (WEF 1995b). Almost 300 WWTPs in the United States are using or plan to use composting for their sludge stabilization and the number of composting facilities appears to continue growing in response to the implementation of Part 503 regulations.

The three types of composting systems (WEF 1995a) are:

1. *Aerated static pile*, in which dewatered cake is mixed with a coarse bulking agent such as wood chips, and the mixture is stacked over a porous bed with air piping connected to blowers. The piles are covered with a layer of finished compost to provide insulation and capture odor. Air is drawn downward or forced upward through the mixture. After composting, the pile is taken down. The bulking agent may be partially recovered by screening and may then be reused.

2. *Windrow process*, in which the mixture is stacked in windrow with a sufficient ratio of surface area to volume to provide aeration by natural convection and diffusion. The windrow is remixed periodically by a turning machine. The amendments are typically of a smaller particle size than with aerated static pile and may include recirculated compost. In the aerated windrow process, natural convection and diffusion are supplemented by forced aeration, as in the static pile process. Air is supplied through trenches in the paved working surface.

3. *In-vessel process*, in which the mixture is fed into one end of a silo, tunnel, or open channel and moves continuously toward the discharge end where it is outloaded after the required detention time. Air is forced through the mixture. The mixture may move as an undisturbed plug or be periodically agitated as it is moved through the vessel.

At present, about 200 biosolids composting facilities are in operation in the United Sates and 50 percent of the composting facilities use static aerated pile systems. If a composting facility were built at West Point Military Academy, an in-vessel composting enclosure would be preferred because the Academy is a tourist attraction and historically preserved site. (It is relatively easier to control odor in an in-vessel process.)

The objectives of composting are to: (1) reduce pathogens to PFRP requirements in Part 503 regulations; (2) further stabilize biosolids by decomposing odor-producing compounds; (3) dry the biosolids; and (4) produce a marketable product. The major factors affecting the compost processes are: biosolids and amendment characteristics (solids content, C:N ratio, particle size and shape, porosity, biodegradability, and energy content); initial mix ratios; aeration rates, and detention time (WEF 1995b). A detailed description of compost processes can be found in Haug's *The Practical Handbook of Compost Engineering* (1993).

The bulking agent or amendments provide energy, are a source of carbon, provide structural integrity, and increase porosity. To allow adequate structural integrity along with porosity and free air space, an initial total solids

concentration of 40 percent is recommended. A wide variety of bulking agents and amendments has been used: wood chips, sawdust, shredded yard wastes, processed agricultural wastes, and shredded tires. Lang and Jager (1993) reported that some amendments such as wood ash suppress compost odors. Reducing particle size increases surface area, thereby enhancing composting rates because the optimum conditions of decomposition occur on the surfaces of organic materials. However, reducing particle size reduces the pore size, limiting the movement of oxygen required for composting. Thus, an optimum range of particle size exists for each condition. For aerated static piles, this is between 12.5 and 50 mm (0.5 and 2 in.), though other process configurations may be able to manage smaller sizes. Coarse bulking agents can be recovered in post processing. Benedict (1986) indicated that compost screening typically results in the recovery of 65 to 85 percent of wood chips entering the composting process.

Carbon and nitrogen are the principal nutrients that affect composting. The carbon-to-nitrogen ratio (C/N) referred to the biodegradable C/N. C/N ratios between 20 and 40 have been cited as optimum. Low C/N ratios (less than 20) result in a loss of excess nitrogen from ammonia volatilization (Haug 1993). High C/N ratios (greater than 80) result in a slowing of decomposition rate and subsequent reduction of composting temperatures (WEF 1990).

The governing air flow rate for forced-aeration composting is dictated by either the need for moisture removal or for temperature control, with temperature control typically being most critical and most easily measured. During the early stages of composting, the temperature of the composting mass is a critical operational consideration. As the compost matures, moisture levels decrease to a point where the need to retain moisture becomes more of a concern than control of temperature. At this point, forced aeration of the compost should be limited, and turning of compost piles can be a more effective way to control temperature. As rule of thumb, aeration demands for temperature control should be approximately 0.2 to 0.25 standard m^3/ton (WEF 1995b, p 45). Haug (1993) discussed theoretical requirements of aeration based on stoichiometry and thermodynamics.

The USEPA (1993) established minimum requirements for composting as a PFRP listed in Appendix B of Part 503 regulations. They are: (1) using either the within-vessel composting method or the static aerated pile composting method, where the temperature of the biosolid is maintained at 55 °C or higher for 3 days; and (2) using the windrow composting method, the temperature for the biosolids is maintained at 55 °C or higher for 15 days or longer. During the period when the compost is maintained at 55 °C or higher, the windrow is

turned a minimum of every 5 days. Most composting facilities are designed and operated with much longer detention time than Part 503 limits. For example, most horizontal agitated systems are designed for 21 days and other in-vessel systems for 14 days aeration, followed by curing.

There are numerous testing methods for measuring compost stability. No single test is universally accepted (Jimenez and Garcia 1989). These test methods (WEF 1995a; p375, Haug 1993, p112) include: (1) testing for percent volatile solids, (2) a respiration test measuring carbon dioxide or oxygen demand, (3) measuring for a C/N ratio less than 20 for mature compost, (4) seed germination and root elongation tests, and (5) measuring redox potential.

Odor control is an important aspect of successful composting operation. For characterization of odors, a WEF manual (1995c) is useful. The treatment methods for compost odors include wet chemical scrubbing; regenerative thermal oxidation; and the use of biofilters, masking agents, and carbon absorption (WEF 1995a). It appears that biofilters using compost and bulking agents have become more popular for odor treatment at composting in the United States.

Construction of an in-vessel composting facility at West Point was considered. The preliminary design and cost data, prepared by International Process Systems Division, Wheelabrator Clean Water System Inc. (IPS, 1995). The total construction cost was estimated to range from $1.6 to $1.9 million. Annual O&M costs are estimated at $60,000. The total area requirement is 39,700 sq ft. Required facilities include:

- 8,000 sq ft (40 x 200-ft) compost building
- four 120-ft bays
- 9,100 sq ft yard waste storage
- 1,200 sq ft compost curing area
- 4,700 sq ft final product curing area
- 4,100 sq ft biofilter.

Required equipment includes:

- composter agitator
- computer control system.

Some operational assumptions of this system are that the installation will compost 40 wet tons of sludge per week. The process requires an additional

bulking agent. The input target solid content is 38 percent dry solids. This can be achieved by mixing 1 ton of sludge at 14 percent solid content with 1.4 tons of yard waste at 55 percent dry solids. Compost detention time is 21 days. Agitation is required 3 to 4 times a week.

Composting West Point sludge at a municipal composting facility was considered. Tri-municipal WWTP was interested in receiving West Point sludge. An author of this report found that the Rockland County Solid Waste Management Authority (RCSWMA) has initiated the construction of a facility to compost the sludge generated from Rockland county's municipal WWTPs. RCSWMA has assured researchers that the composting facility had sufficient capacity to process additional sludge from Target Hill WWTP (Appendix C).

West Point Military Academy will realize a substantial savings by composting the Target Hill WWTP sludge and using the resultant biosolids as a soil supplement. A benefit is analysis follows.

About 1,840 cubic yards of sludge was disposed by landfill annually. The tipping fee was $62.50/cu yd. Transportation costs were $160 per 20 cu yd container. The disposal cost was $129,620. Sand purchase cost for 184 tons was $2,024 ($11/ton) and labor cost for mixing sand with sludge was $7,800 (520 workhour at $15/hour). West Point Military Academy bought about 600 cu yd of bulk soil amendment and 1,500 bags of 3 cu ft packaged soil amendment in addition to 77 tons of fertilizer. The bulk soil amendment was about $25/cu yd and each 3 cu ft bag cost $10. The total soil amendment purchase cost was $30,000. The total cost for sludge disposal and soil amendment purchase costs were $169,444.

If sludge is composted and biosolids are used as a soil amendment, the total sludge stabilization and soil amendment cost will be $111,510, assuming 1,656 cu yd sludge at $60 per ton for composting and $150 per pick-up of 20 cu yd container. By this calculation, annual savings by using the RCSWMA composting facility will be $57,934.

Autothermal Thermophilic Aerobic Digestion

Much of developmental work leading to the autothermal thermophilic aerobic digestion (ATAD) process was completed by Pope in Germany in the 1970s; the systems have since been in operation in Europe. However, when the Part 503 regulations were implemented in 1993, the ATAD process was revived as an emerging technology capable of meeting PFRP requirements of Part 503 regulations. The ATAD systems normally use a two-reactor aerobic process that operates under thermophilic temperature conditions (40 to 80 °C) without

supplemental heat. Typical ATAD systems operate at 55 °C in the first reactor and reach 60 to 65 °C in the second reactor (USEPA 1990). If sufficient insulation, hydraulic retention time, and adequate solids concentration are provided, the process can be controlled at thermophilic temperatures to achieve the pathogen reduction and vector attraction requirement (greater than 38 percent volatile solids destruction) to meet the Part 503 regulations Class A requirements (WEF 1995a). Since operating temperatures exceed 40 °C in the reactor, nitrification is inhibited and cell mass is degraded as follows:

$$C_5H_7NO_2 + 5O_2 \rightarrow 5CO_2 + 2H_2O + NH_3 + \text{Energy}$$

This indicates that approximately 1.5 kg of oxygen is required per kg of volatile solids destroyed. Energy produced is approximately 21,000 kJ/kg of volatile solids destroyed.

Key design features (WEF 1995a) are that:

- By gravity or mechanical thickening, the influent of ATAD should achieve a minimum suspended solids concentration of 3 percent. The feed must have a chemical oxygen demand of 40 mg/L or greater.

- A minimum of two enclosed/insulated reactors should be provided in series. In a single-reactor system, pathogen reduction may be less due to short circuiting.

- After the ATAD process, 20 days cooling is recommended. If heat exchangers are used, post cooling time can be reduced to 1 to 3 days.

A solids retention time of 15 days or less should be maintained so that volatile solids reduction via endogeneous respiration in the aeration basin is kept to minimum. German design standards allow 5 to 6 days hydraulic detention time. In the United States, one of the processes to further reduce pathogens (PFRPs) listed in Appendix B of 40 CFR Part 503 is thermophilic aerobic digestion. The requirements are that: liquid biosolids are agitated with air or oxygen to maintain aerobic conditions, and the MCRT of the biosolids is 10 days at 55 to 60 °C (USEPA 1993).

Various aeration and mixing devices have been used: aspirating aerators; a combination recirculation pump/venturi arrangement; turbine; and diffused air.

Foam control plays an important role in ATAD. Wolski (1985) reported that the foam layer affected oxygen-transfer efficiency and enhanced biological activity.

However, if the foam is left uncontrolled, an excessively thick foam layer forms and results in foam loss from the reactor. Several methods to control foam were used: mechanical horizontal shaft foam cutter; vertical mixers and spray systems; and chemical defoamers.

Post-ATAD biosolids typically "gravity thickens" to 6 to 10 percent solids. Deeney et al. (1993) reported that a 10-day HRT was best when biosolids from the ATAD were dewatered directly.

Baier and Zwiefelhofer (1991) discussed current operations of ATAD in Europe and the benefits of ATAD as a pretreatment step to an mesophilic anaerobic digestion. They claimed enhanced volatile organic degradation, gas production, and better dewaterbility in comparison with anaerobic digestion. The ATAD pretreatment system could provide West Point WWTP with "Class A " sludge, which can be land applied or further processed for the beneficial use. It may be of interest for West Point Military Academy to evaluate pre-ATAD process if liquid sludge is to be directly land applied.

Sludge dryers

Dryers are designed to evaporate water from sludge by applying heat. PFRP heat drying requirements in Appendix B of Part 503 regulations are that:

> Biosolids are dried by direct or indirect contact with hot gases to reduce the moisture content of the biosolids to 10 percent or lower. Either the temperature of the biosolids particles exceeds 80 °C or the wet bulb temperature of the gas in contact with the biosolids as the biosolids leave the dryer exceeds 80 °C.

Conventional dryers include direct dryers (flash dryer, rotary drum dryer, and fluidized bed dryer), indirect dryers (paddle dryer, rotary disc dryer, and multiple-effect evaporation dryer), direct-indirect dryers, and infrared dryers (WEF 1995a). Emerging dryers include multistage tray dryers, multipass dryers, metal hydroxide biosolids volume reducers, SDS infrared dryers, ball dryers, Centridryers, and spray dryers (EPRI 1995).

Rotary drum dryers and rotary disc dryers are the most commonly used dryer technology in the United States. Preliminary data indicates that several of the emerging processes may be cost competitive.

A primary consideration in the assessment of drying technologies is the requirement for air emissions control. Heat drying processes release gaseous

sidestreams that may contain volatile organic compounds, ammonia, and hydrogen sulfide (EPRI 1995).

Emerging technologies include multistage tray dryer, multipass dryer, infrared dryer, ball dryer, centridryer, and spray dryer (EPRI 1995).

The multistage tray dryer is a vertically oriented vessel into which solids are fed from the top and moved by rotating arms from one heated tray to the next in a zigzag motion until they exit at the bottom as a dried, pelletized product. The system has operated in Bruges, Belgium, producing a pelletized sludge for incineration.

The multipass dryer is very similar to the multistage tray dryer in that solids are introduced into a top inlet of the dryer and drying is achieved by moving the solids through a series of levels. However, in the multipass dryer, the biosolids are moved by a series of stainless steel belts and the dryer vessel is horizontally oriented. The biosolids are dried by direct and indirect heat. The system is factory assembled and ready for field hookup.

The infrared sludge dryer has infrared heating elements and augers in two horizontal drying zones. The augers agitate biosolids to maximize exposure to the infrared radiation. The heat from infrared elements dries sludge and kills pathogens.

The ball dryer uses air and plastic or stainless steel balls. Liquid residues are sprayed and distributed into top of the dryer. Drying is accomplished with counter current or co-current air flow when the dried product is separated from the balls, the product is air conveyed to a cyclone and the balls are recirculated. The dryer is capable of operating on a variety of fuels and can produce "Class A" biosolids.

The centridry process combines mechanical dewatering with thermal drying in a single element. It can produce "Class B" biosolids.

It may be of interest for West Point Military Academy to evaluate the potential use of a low price drier to dry from 13 to about 30 percent solids.

Other Emerging Stabilization Techniques

In response to the implementation of Part 503 regulations, emerging biosolids stabilization processes have been developed. These processes include: acid

oxidation/disinfection, heat treatment/acid digestion, heat/wet oxidation, and active sludge pasteurization (WEF 1995).

Conditioning/Dewatering

Conditioning enhances the aggregation of suspended sludge particles by chemical and physical means. Conventional conditioning methods include: the use of polymers, inorganic chemicals, and heat treatment. A detailed discussion of conditioning can be found elsewhere (WEF 1988).

Emerging conditioning technologies include: electric arc treatment, mechanical freeze/thaw, electro-acoustical conditioning, radiation treatment, and microwave methods (EPRI 1995). The electric arc process uses a pulsed power driven electric arc in the liquid sludge. The intense electrical arc provides sludge with shock wave, ultraviolet, -OH radical, and ozone. The electrical arc enhances dewaterability as a result of rupturing the micro-organism's cell walls. Polymer cost is reportedly decreased due to reduced use. This Russian technology is patented by Scientific Utilization, Inc., Decatur, AL. At least five different mechanical freeze/thaw methods were proposed or demonstrated. Electro-acoustical conditioning uses electrical and acoustical fields to enhance conventional mechanical dewatering. Smollen and Kaffar (1994) demonstrated electro-osmotic dewatering to enhance belt press efficiency. This process has a South African patent.

Polymer Characterization and Control

To select conditioning polymers, laboratory tests such as the Buchner Funnel test, capillary suction time (CST), or specific resistance tests are often used (Vesilind 1979) and WERF (1993) has provided a guidance manual. Streaming current detector or nuclear magnetic resonance (NMR) analysis were used to accurately quantify polymer dosages (WERF 1995). However, none of these tests can accurately predict actual dewatering; full scale evaluation should be performed under real world conditions.

Mechanical Dewatering

Dewatering is the removal of water from sludge to achieve a volume reduction greater than that achieved by thickening alone. Conventional mechanical dewatering technologies include the use of the belt filter press, centrifuges, vacuum filter, and plate press. Belt presses are a primary means of mechanical dewatering for small and medium-sized facilities, and are also routinely used at

large facilities. Capital cost usually prohibits the use of centrifuges at small facilities. High-torque centrifuges usually produce a drier cake than belt press; however, they are not routinely recommended unless the ultimate use of biosolids dictates their use. Emerging mechanical dewatering technologies include the membrane belt filter, crossflow membrane filter, python pinch press, Fournier rotary press, and screw press. Of these emerging technologies, only Fournier rotary press has been used at full-scale WWTP operation. In the Fournier press, biosolids are fed into a peripheral channel, the walls of which are made up of rotating filtering elements that allow the liquid to pass through while retaining the solids. A rotating wheel generates a compressive and driving force on the solids cake formed. About 40 percent solids contents and more than 90 percent solids capture were reported (EPRI 1995).

One mechanical system considered feasible for small treatment plants is the Alar vacuum filtration system. Traditional vacuum filtration is one of the oldest dewatering technologies used in municipal WWTPs. The principal of vacuum filtration is that, by applying a vacuum opposite the filtration media, atmospheric pressure may be used to drive the liquid from the solids. A rotating surface drum is covered with some type of media, and creates three zones of subsequent operation: cake formation, cake dewatering, and cake discharge. Rotary vacuum filters have significantly lost popularity in comparison to other mechanical dewatering systems, largely due to the complexity, conditioning requirements, and excessive operation and maintenance costs associated with such systems.

Alar technology claims to have overcome the disadvantages of traditional rotary vacuum filtration. The system is designed for smaller treatment plants; the vendor suggests a maximum plant size of no greater the 2 MGD. However, the primary reason this study examined the system was for its ability to produce dewatered solids consistently in excess of 25 to 30 percent solids. The major difference between Alar technology and conventional rotary vacuum filtration is that Alar uses a precoat of diatomaceous earth (DE) on the filter media throughout a dewatering run. Also, conventional filtration typically involves the addition of a sludge conditioner, such as polymer, but the Alar system requires none. One aspect of the Alar system that suits West Point is that its optimal influent solids operating is rather low, ranging from 2 to 4 percent. This is well suited for the sludge from the digesters at West Point, since operators have indicated that they average 3 percent solids. Conventional vacuum filters typically require a higher solids for suitable operation, generally near 6 percent.

The Alar system itself consists of two main operating units: the filtration unit itself and a vessel used in making the DE slurry for precoating the rotating

drum (filter aid mixing tank). Startup of a run requires that the operator add the required amount of DE to the vessel. After the addition, potable water is added and mixed to form the desired slurry. The slurry is then gravity fed into the sludge basin in the filtration unit. After applying the vacuum, the DE is picked up onto the filter to form a precoat of approximately 3 in. in thickness for an 8-hour run. The system is now ready for sludge to be sent to the sludge basin of the Alar filter, provided it is no greater than 3 percent. The Chandler WWTP, which was visited to review the Alar system in operation, has a 6 percent solids coming in and therefore dilutes the sludge to achieve better performance. The startup phase appeared to require low operator attention, and was completed in less than 30 minutes. With the automation option, the operator simply adds the DE and presses a start button on the control panel. Without the "auto" option, the operator must turn on the pump and drum drive to precoat. It is also possible to start a second batch of sludge without an operator present if the auto option is installed.

Once the system is running, it seemed to require little attention. Since the precoat serves as the filter media, it is continuously removed so that binding is never a problem. Note that this evaluation occurred after a period of operation that allowed the operators to identify the best operating parameters for the sludge being applied. The main operation variables of the Alar system are drum rotation speed, knife advance, and liquid depth of sludge in the basin of the unit. As the drum speed is increased, the sludge treatment capacity is elevated, but the time for filtration is decreased. This results in a lower solids concentration. The Alar system has a continuously advancing knife to remove a thin layer of dewatered sludge. The speed of the knife-advance motor must not be too fast or the run time will be unnecessarily short. When the knife has advanced and removed the all of the precoat, the run must be stopped and a new DE layer added. The depth of sludge in the basin also affects the drying time on the filter, and therefore the dewatering performance. As the depth is increased, greater capacity is gained, but the system may produce lower solids as a result. The operator indicated that once these variables are set, the system basically runs itself. At the completion of a run, the system cleans itself with a spray bar located along the drum.

The manufacturers claim of a high solids concentration were verified at the Chandler WWTP, where the operator stated that the system never produced less than 25 percent solids. The Chandler WWTP has an extended aeration system and aerobic digestion, so, as at West Point, there is a significant portion of difficult-to-dewater biosolids. One reason that the dewatered sludge has such a high solids concentration is the presence of the DE precoat, since the knife removes dewatered sludge as well as dry solids of the precoat. The Alar

representative stated that 5 lb/sq ft of DE is added at the start of a run. The Alar Model 660, which has 113 sq ft of surface area, therefore requires 565 lb (12 #50 bags) of DE for one 8-hour run. The addition of these external solids serves to increase the percent solids, but also adds to the solids for ultimate disposal. One operating characteristic of any mechanical dewatering device that must be considered is the quality of filtrate. Visual inspection at the Chandler WWTP confirmed that an exceptionally clear filtrate was returned to the head of the plant. The Alar system can be considered next to the RCSWMA composting option.

Contracted Mobile Dewatering Service

As an interim solution to the sludge dewatering problem at West Point, a mobile dewatering service could be contracted on an annual basis. Several contractors are willing to perform such a service, and are listed in the *Pollution Equipment News Buyers Guide* (1995). Such turnkey operations include mobilizations of equipment, provision of technicians and operators to run the dewatering device, and any required dewatering aids (e.g., polymer). Thus, a cost benefit is realized by eliminating the O&M requirement for the BFP, which is estimated at $22,500 for a typical WWTP. The only cost incurred by the WWTP is for electricity and water to run the equipment.

However, the cost to dispose of the dewatered sludge is still incurred by the WWTP. The feasibility of using such a service would require that it meet the minimum 20 percent solids content required in NYCRR, but to ensure that it is cost effective, a higher solid content may be required.

The primary dewatering service considered for West Point uses an MSE filter press. This service is willing to accommodate the relatively small sludge flows at West Point, and guarantees a minimum of 35 percent solids with its dewatering equipment. Filter presses operate in a batch mode by forcing water from the sludge under extremely high pressures. Advantages for using the filter press are its ability to generate high cake solids and clear filtrate, and its good solids capture rate. Several disadvantages of using the filter press are: its great mechanical complexity, high chemical costs, high labor costs, and its requirement for routine replacement of parts. However, the use of such a press in a service mode would essentially eliminate all of the disadvantages because these problems would become the responsibility of the dewatering service. Literature and video tape on the principles and operation of the MSE press have been forwarded to West Point. This study recommends a trial of contracted dewatering.

Natural Dewatering

Conventional dewatering technologies include the use of drying beds, wedgewater beds, vacuum-assisted beds, and sludge lagoons. In the United States, many small WWTPs use sand-drying beds for sludge dewatering. These sand-drying beds can be upgraded with wedgewater beds, vacuum-assisted beds, or reed beds (Kim 1992; 1993). Reed beds represent an attractive technology in terms of economy and technical reliability. Although it was started in Europe more than 10 years ago, reed bed dewatering is still an emerging technology in the United States. Like sand drying beds, the reed bed is a natural dewatering system and is thus well suited for smaller plants. Compared to mechanical dewatering processes, O&M costs of reed beds are significantly lower than those of alternative systems because of the reed bed's low level of complexity, minimal requirement for operational attention, and reduced energy requirements. A disadvantage associated with such natural systems is the greater requirement for available land, which is the main obstacle in the adoption of reed beds at West Point. The reed bed process can produce a much greater solids content than mechanical systems, with solids ranging from 30 to 60 percent.

The reed bed process basically operates as a modified sand drying bed with a dense growth of reed vegetation. Therefore, the construction is similar to that of sand drying beds. An excavated trench is first lined with an impermeable barrier to contain the liquid. Precast Hypalon liners have been successfully demonstrated for lining the trenches at several installations. The freeboard over the sand layer should be a minimum of 1 m, but has been shown to be functional up to 5 ft at the Fort Campbell site. This height of freeboard is required to ensure adequate storage capacity of the sludge, which is designed for 10 years' use. The beds are constructed as a series of cells, with a typical size of 50 x 100 ft each.

Once the beds are constructed, the reeds are planted at 1-ft centers. Several species are available, but generally the common reed *Phragmites* is used. *Phragmites* is well suited for reed bed use because of its great tolerance for variable climates and elevated evapotranspiration rate. Once the reeds are established, sludge may be applied to the beds. Reed beds are designed to accommodate stabilized sludge that contains 3 to 4 percent solids. The West Point sludge meets these requirements. Reed bed technology has been largely used in the northeastern states, including New Jersey, Pennsylvania, Maine, and Vermont; therefore West Point should have weather similar to that at facilities already successfully using reed beds.

Reed beds have some important advantages over other natural systems. The dried sludge removed at the end of bed use is very similar in quality to compost with regards to pathogen content and stabilization. This is mainly due to the long detention of the sludge, added microbial degradation due to the oxygen provided through the root system, and an additional storage period that follows the final sludge addition. While not yet documented, it is believed that, if the sludge is allowed to weather for 1 year following the final sludge application, it will pass the EQ sludge criteria.

Reed beds require very little operator attention. Typical operation attention is 200 hours per year to monitor sludge additions and perform other miscellaneous tasks. Unlike sand beds, which require the removal of the sludge after each individual sludge application, the reed beds is designed to hold sludge for a period of 10 years. One relevant manpower requirement is for harvesting of the reeds each fall. Harvesting may be performed manually with hedge clippers, sickles, or mechanical devices. Alternately, the reeds may be burned after filling the bed with 2 in. of water, if the State permits. One commonly occurring problem with the reed bed is infestation, especially by aphids. This problem is typically controlled by purchasing lady bugs, a natural predator of the aphids.

The root system of the reeds enable long-term storage through evapotranspiration and by maintenance of a pathway for the liquid to drain through. Also, at the time of disposal, the final volume is significantly lower than the total volume from a sand bed after 10 years, which results in disposal savings as well. Several ultimate disposal alternatives are available for the sludge after it is removed from the beds. It is likely that the weathering of the sludge over the storage period will result in Class A biosolids. Therefore, the material could be freely used as any commercial soil conditioner, in a similar manner to compost. One problem that must be considered is the removal and extinction of the reed system from the compost. This may possibly be addressed by killing the reeds at the beginning of the 1-year holding period and screening the final product. In the worst case, the biosolids would still meet the Class B standards, and could still be beneficially applied to the land. The great solids content of over 40 percent would facilitate ease of application. Recall that Part 503 does not require site restrictions for the addition of Class B sludge. If nonpublic contact areas such as the range land where leaf compost is currently spread are used, only a 30-day site restriction would be necessary. Finally, landfilling of the sludge is still an alternative. Landfilling would still be cheaper than currently practiced, since the volume of sludge would be reduced through greater solids concentration, organic destruction, and elimination of sand addition. Finally, with the implementation of this natural dewatering system,

the belt press could be eliminated from operation, which would also increase cost savings, and simplify and ease of plant operation.

Winter operations are a concern when using natural, outdoor processes for the West Point facility. As reed dormancy during winter affects the rate of water uptake, sludge application is normally stopped in the winter. New Jersey experiences a downtime of only 20 to 30 days annually, but areas with more severe and extended winters will experience greater periods of reduced dewatering capability.

If West Point cannot store the sludge through the worst winter months, provisions must be made to address this issue. Some sludge may still be applied to the reed beds even if the reeds are dormant or harvested, but care must be taken to ensure that the sludge level does not exceed the height of the remaining reed stalk. During winter, the freeze/thaw mechanism will effectively reduce the volume of sludge that is applied. It would be also be advisable to empty the digester in the late fall to maximize the plant's storage capacity for the winter months.

Design parameters for reed beds depend on a number of variables that significantly affect the dewatering rate. Experience at Fort Campbell indicates that approximately 20,000 sq ft of reed bed area is required per 1 MGD of wastewater flow when anaerobic digestion is used for stabilization. By this formula, the West Point Facility would require around 40,000 sq ft for the current design capacity. The average solid loading rate for 16 operational systems in New Jersey, New York, and North Carolina on reed beds for aerobically digested sludge is about 17 lb/sq ft/yr (USEPA 1985). This solids loading rate would result in a requirement of nearly 34,000 sq ft for the present estimated solids production of 290 dry ton/yr. Reed bed systems are always run with multiple beds. A typical size for a reed bed dewatering cell is 50 x 100 ft, for a total area of 5000 sq ft per cell. A minimum of two additional cells are required, to assure that a reed bed could remain idle prior to its excavation and for emergencies. This detention time in the last year provides additional storage and pathogen destruction on the top layer, and may result in generation of EQ biosolids.

The Reed bed alternative will not be implemented at West Point Military Academy due to limited space. Appendix A to this report summarizes a case study at Fort Campbell, KY WWTP. Sludge management options were evaluated and operational and costs data are presented.

Agitated drying is also a fairly new method. The Metropolitan Water Reclamation District of Greater Chicago used an agitated drying method. Dewatered sludge from centrifuges or lagoons is placed on a mildly sloped paved drying surface. The sludge is then spread out over the surface to a depth of about 45 cm. The sludge is then agitated by "Brown Bear" tractor equipped with a front mounted auger until the solids content reaches 30 percent. The biosolids is windrowed and periodically agitated until the solids content reaches 50 percent (Lue-hing 1992, p 291).

A simple approach being considered for West Point is to use natural air drying of the sludge following belt filter press dewatering. Water is removed from sludge by two basic mechanisms: drainage and evaporation. Using this approach, the most easily removable liquid is first removed in the belt press. This will greatly reduce the volume of sludge that will be required for subsequent drying. For example, if the sludge is dewatered from a 3 to a 13 percent solids content, the volume will be reduced nearly fourfold, and will reduce the required area for the air drying pad. This differs from conventional sand-drying beds, because they are designed to promote both free water drainage and evaporation. Typically, the first filtration stage of dewatering on sand drying beds takes 2 to 3 days, and yields 12 to 15 percent solids (Nebiker 1967). After filtration, the rate of dewatering depends on the weather conditions, specifically the rates of evaporation and rainfall. The proposed design will eliminate the need for the filtration stage on the drying pads, and the dewatering rate will be a function of rainfall and evaporation. However, to minimize the required area, the proposed drying pad will be covered. Therefore, the rainfall factor is eliminated from consideration.

Use of the air drying pad is being considered as a simple and readily implemented approach to improved sludge management as West Point. The system will demand relatively low capital and O&M cost. Difficulty with the system is mainly focused on limited effective drying in winter months (unless the bed is covered) and the requirement for land close to the WWTP. Air drying is also recommended as a preceding step to composting, because it would greatly reduce the amount of bulking agent required and size of the composting process.

This study also recommends that an air drying pad and agitated drying be tested. The space opposite to track field in Target Hill WWTP can be used for this purpose. A "Brown Bear R24C aerator/auger" (about $10K) is a tool recommended for use in this process. A potential problem at this location is one of aesthetics. West Point may not allow sludge drying on the Academy premises. An additional problem may be the space requirement for the drying pad and storage area. Design data still need to be obtained from field tests. If

solids content is increased from 14 percent to 28 percent, the wet sludge volume will be about half of present generation volume, yielding savings to West Point of about $50,000 per year due simply to volume reduction to composting/disposal site. The estimated construction cost for the roofed air drying pad, side wall drainage, and agitator is $260K.

Another innovative method to enhance dewatering is to use an electric arc to break sludge cells. It may be of interest to try this technology.

Beneficial Use

Land Application

Land application is application of biosolids to land either to condition the soil or to fertilize crops or other vegetation grown in the soil. Based on information in the Preamble to Part 503 (USEPA 1993), 33.3 percent of U.S. sludge is land applied. More than 65 percent of land-applied biosolids are placed on agricultural crop land. Of the remaining sludge not land applied, 34.0 percent is landfilled, 16.1 percent incinerated, 10.3 percent disposed into surface impoundments, and 6.3 percent disposed of by unknown means. In the future, the ability to landfill biosolids will be continuously reduced; land application or beneficial use of biosolids will increasingly take the place of landfills. Case study information on land application is available elsewhere (WEF 1994b; WERF 1993).

If West Point Military Academy uses the RCSWMA composting facility starting from 1998 and the processed compost meets exceptional quality standards, then the compost may be freely used as a soil supplement for landscaping.

In 1990, the U.S. Army Environmental Hygiene Agency (AEHA), currently known as the Center for Health Promotion and Preventive Medicine (CHPPM), studied the feasibility of applying approximately 2 million gal per year of liquid to the Gaillesville Training area. AEHA used $60 per dry ton for disposal cost calculation and concluded that land application was four times more expensive than landfill. However, in this case, if the calculation had measured the waste in wet tons rather than dry tons—as the quality of the waste would indicate—land application would have shown itself to be cheaper than or comparable to landfill.

Incineration

Incineration of sludge may be cost effective in large metropolitan areas due to transportation costs and the limitation of other choices. Although sludge incineration reduces concerns for water pollution, atmospheric pollution from incinerators and safe disposal of residual ash are serious concerns.

In the United States, of about 150 sludge incinerators in operation, about 70 (mainly small sludge incinerators) have been shut down. The primary reason for the shutdowns was that there were lower cost alternatives to incineration (USEPA 1985). Most incinerators in the United States are either multiple-hearth furnace and fluid bed reactors. Although multiple-hearth furnace have been preferred to fluid bed reactors in the past, the trend in new furnace construction is to employ fluid bed reactor technology. European and Japanese processors have used fluid bed reactors for some time. A more detailed discussion of incineration technologies is available elsewhere (WEF 1992).

In NYSDEC Region 3, Westchester County have more incinerators than any others. Because of long distance between West Point and Westchester County and cost, incineration is not considered as an option for West Point sludge.

5 Summary and Recommendations

The Target Hill WWTP at West Point generates about 1,840 cu yd (about 250 dry tons) of sludge with 13 to 14 percent solids content. The sludge is currently mixed with sand to meet the 20 percent solid content required by New York State, before it is disposed at the Al Turi landfill. This study has developed a sludge management strategy for the Target Hill WWTP that considers the new USEPA Part 503 regulations, economic benefits, and simplicity of operation.

This study compiled field and regulatory data and briefly discussed the regulatory framework of Part 503 regulations to give a better understanding of the possibilities of beneficial use of sludge. The study summarized emerging sludge management technologies and evaluated whether the West Point Military Academy WWTP can cost effectively adopt any of these technologies. Information was also collected how other municipal WWTPs manage sludge.

This study recommends that:

1. The Target Hill WWTP compost its sludge at the Rockland county central composting facility, which is expected to begin operation in January 1998 by the Rockland County Solid Waste Management Authority, and use the composted biosolids as a soil amendment at the West Point Military Academy. Annual savings of about $58,000. By implementing this recommendation, Target Hill WWTP will be able to save O&M money and serve as a model installation for Federal and local government cooperation in biosolids management.

2. Target Hill WWTP should pilot test agitated drying on air drying pad using horizontal auger/aerator for additional dewatering.

3. West Point should continue to explore other emerging sludge management/treatment technologies. For example, if space becomes available adjacent to the Target Hill WWTP, reed bed technology should be pursued.

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Appendix A: Case Study—Reed Bed for Sludge Dewatering at an Army WWTP

The U.S. Army Construction Engineering Research Laboratories (USACERL) has been working on developing and adopting improved sludge dewatering systems for U.S. Army wastewater treatment plants. USACERL selected reed beds as the best alternative for future Army sludge dewatering systems based on the system's economical and technical feasibility and on a demonstration of the technology at Fort Campbell, KY.

This Appendix compares the Army's options for upgrading Fort Campbell's sand-drying beds, analyzes costs, discusses sludge hydraulic and solids loading rate data from existing reed bed operations in the United States, and presents 5 years' operational data and recommendations for improvement. Options considered for comparison included: land application of sludge at training fields, wedgewater beds, vacuum-assisted beds, wedgewater beds and composting, mechanical dewatering systems, and a "no change" option in which sand-drying beds would have been retained.

This Appendix also summarizes advantages and limitations of reed bed sludge dewatering. Advantages of reed beds may include: Low investment especially when a sand-drying beds are converted to reed beds, savings from sludge removal costs, and the benefits inherent to a simple and economical technology. Limitations may include: large land requirements and little scientific understanding of this empirical technology. The challenge will be to further develop an appropriate disposal technology to meet new U.S. sludge regulations.

Introduction

Sludge dewatering involves removal of water to reduce the sludge volume and to meet the target solid concentrations for the subsequent treatment and disposal. The key factors to select a dewatering method should be the economics of total sludge management and overall efficiencies. Operators of small domestic wastewater treatment plant (WWTP) operators are faced with a unique problem of sludge dewatering and disposal; the small plants generate too little sludge to effectively use the innovative or sophisticated reuse or treatment technologies,

but enough sludge to make it difficult to meet technical and economical requirements.

Many small WWTPs in the United States still use conventional sand-drying beds to dewater sludge. Sand-drying beds are simple to operate and maintain, and are inexpensive to build. However, sand-drying beds can have long dewatering times (2 to 4 weeks), intensive labor requirements to remove dried sludge, and can experience clogging. The U.S. Army operates over 100 small wastewater treatment plants, most of which employ conventional sand-drying beds to dewater sludge. Thus USACERL has evaluated a number of opportunities to improve current sludge dewatering at the Fort Campbell, KY WWTP. Mechanical dewatering, land application, wedgewater bed, vacuum-assisted beds, and reed beds were considered. Because the U.S. Army Installations generally have excess capacity in sand-drying beds, simple retrofit of sand-drying beds to reed beds would provide the Fort Campbell with the greatest benefit. As a result, USACERL demonstrated reed bed dewatering at Fort Campbell. The reed beds of about 2,200 m^2 (20,000 sq ft) could dewater about 35 percent of sludge generated from Fort Campbell WWTPs treating about 11,000 m^3 (3 million gal) per day for last 5 years.

Technical Data Compilation on Reed Beds

The reed bed is an innovative sludge dewatering process that uses both the reed's evapotranspiration capability and sand-drying bed's gravity drainage. The reed *Phragmites* is a tall annual grass with an extensive perennial rhizome. *Phragmites* is well suited to sludge dewatering because it is characterized by its extreme tolerance to variable environmental conditions and its high evapotranspiration rate (USEPA 1988). It was found that reeds are capable of creating aerobic microsites (adjacent to the roots) in an otherwise anaerobic environment in sludge. This can assist in sludge stabilization and mineralization (Reed et al. 1988). The reed beds can be easily modified from sand-drying beds by planting the reeds in the sand layer and adding 1 to 1.5 m (3 to 5 ft) freeboard above the sand-drying bed side wall to provide long-term sludge storage. Reeds are planted usually with the density of 1 plant/sq ft (30-cm centers).

USACERL sent questionnaires to 44 WWTPs that used sludge dewatering reed beds and received technical data from 24 WWTPs and visited a few sites for further data in 1990 and 1992 (Kim et al. 1993). The questionnaire was divided into seven areas of inquiry: design data, construction costs, O&M, bed performance, start-up data replanting data, and general information relating to

reed bed performance. Most of the reed bed facilities were new and were located in the northeastern United States. The oldest reed bed facility in the United States was 10 years old. The data indicated an increasing trend towards reed bed dewatering systems. The reed beds were fed with anaerobic digested (6 WWTPs), aerobic stabilized sludge (14 WWTPs), and others (4 WWTPs). Most all the WWTPs treat an average daily flow rate of less than 3,785 m^3 (1 MGD) per day.

Hydraulic Loading Rate

The total annual sludge loading rate on the reed beds ranged from 53 m^3/yr (14,000 gal/yr) to 4,061 m^3/yr (1,080,000 gal/yr). Of the facilities dewatering anaerobic digested sludge, the hydraulic loading rate ranged from 0.16 m/yr (4 gal/sq ft/yr) to 0.98 m/yr (24 gal/sq ft/yr). Of the facilities dewatering aerobic stabilized sludge, the hydraulic loading rate ranged from 0.73m/yr (17.9 gal/sq ft/yr) to 7.3 m/yr (179 gal/sq ft/yr).

Figure A1 shows the yearly average operational hydraulic loading rate data versus the solids contents. The hydraulic loading rate appears to be insensitive to solids content of sludge. Hydraulic loading rates for anaerobic digested sludge are much lower than those of aerobic stabilized sludge. A plausible reason for the big difference may be that the evapotranspiration of reeds could be higher for aerobic sludge than for anaerobic sludge.

Considering the highly loaded beds are operated with healthy growth of reed, the low load beds appeared to underuse the reed bed capacity.

Solids Loading Rate

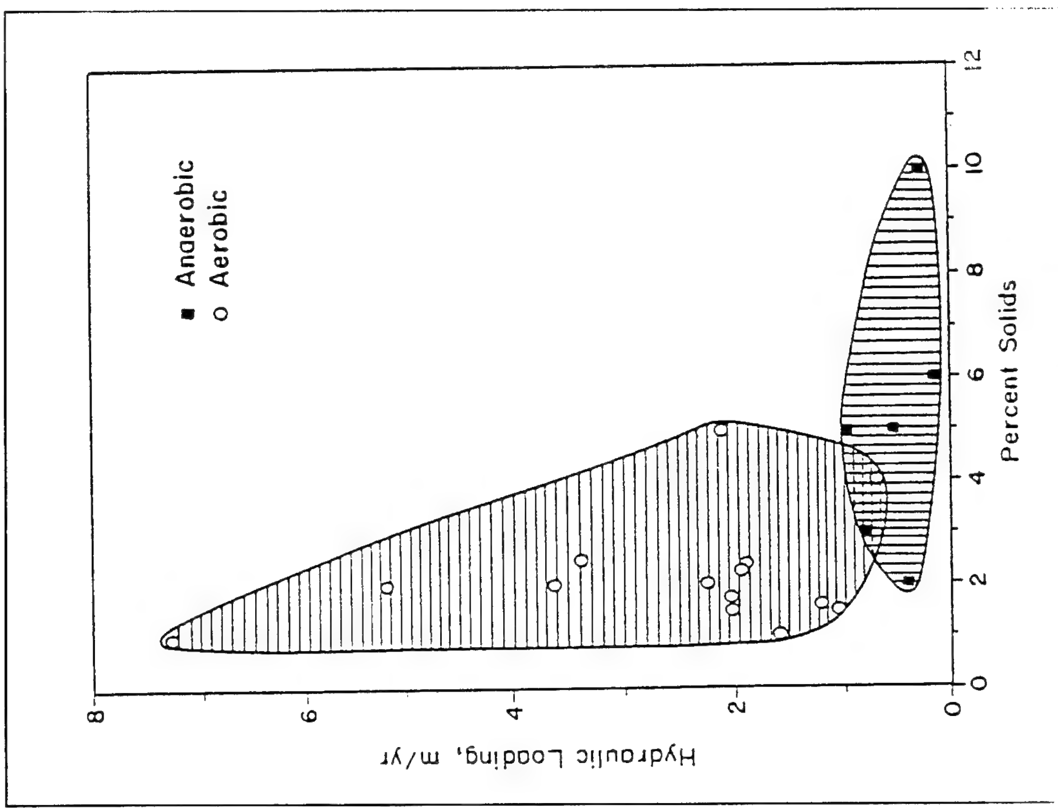
Solids content of aerobic sludge ranged between 1 percent to 5 percent and that of anaerobic sludge between 2 and 10 percent. Of the beds dewatering anaerobic digested sludge the solids loading rate ranged from 13 kg/m^2/yr (2.6 lb/sq ft/yr) to 60 kg/m^2/yr (12.3 lb/sq ft/yr). Of the beds dewatering aerobic stabilized sludge, loading ranged from 16 kg/m^2/yr (3.3 lb/sq ft/yr) to 106 kg/m^2/yr (21.7 lb/sq ft/yr). Figure A2 shows the yearly average operational solids loading rate data versus solid contents. Although aerobic digested sludge has a lower percentage of solids, its solid loadings are higher than anaerobically digested sludge. By comparison, the USEPA (1987) reported that the average solids loading rate for 16 operating facilities in New Jersey, New York, and North Carolina was about 81 kg/m2/yr (17 lb/sq ft/yr).

Sand-drying beds have been built with varying design criteria. The 1978 Ten State Standards (Great Lakes Upper Mississippi River Board of State Sanitary Engineers) recommended 1.0 sq ft/capita as sand-drying bed area requirement and the Army Technical Manual 5-814-3 (1978) allows 2.5 sq ft/capita. Using the 1990 Ten State Standards loading recommendation and Army's drying bed criteria, the solid loadings for open sand-drying beds range from 64 to 113 $kg/m^2/yr$. The USEPA (1987) recommended 100–160 $kg/m^2/yr$ as a sand-drying bed design criteria for anaerobic sludge.

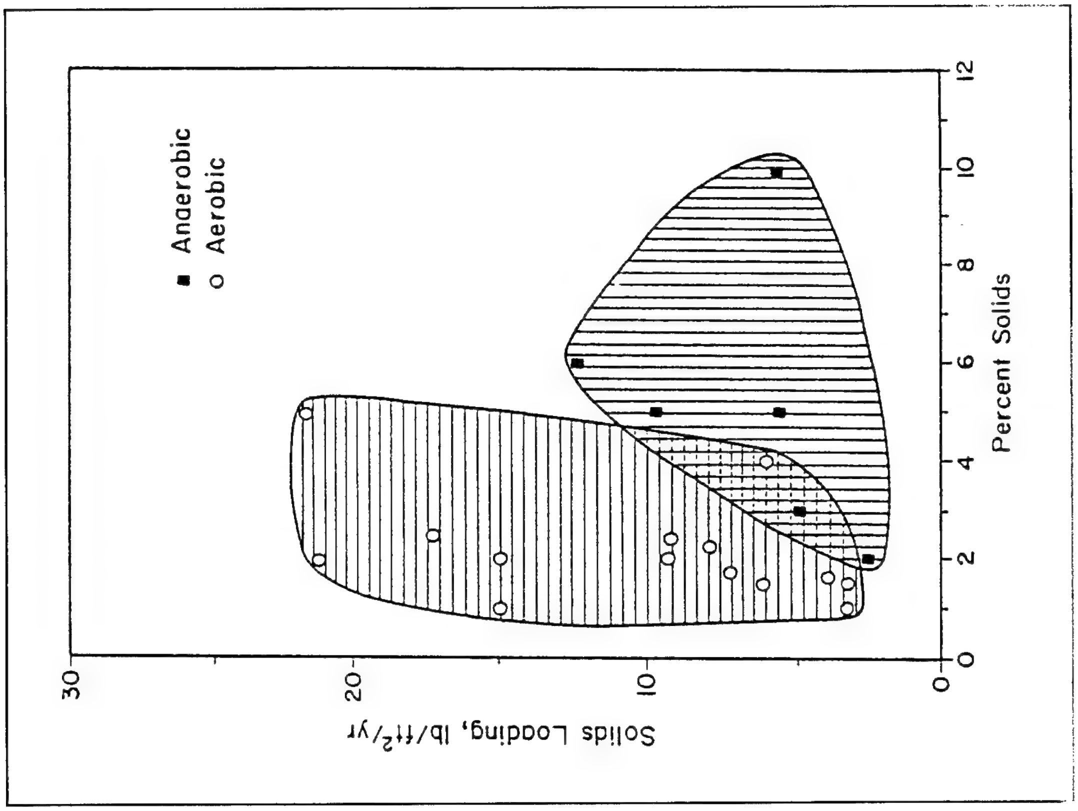
The comparison between reed bed operation data and sand-drying bed criteria indicates that the existing reed beds generally are loaded less than sand-drying bed's design capacity. Where the reed beds perform less than sand-drying beds, a 100 percent retrofit of sand-drying beds may not meet the sludge dewatering requirements so that construction of additional new beds may be needed. Since the data only presents operational loading and no logical loading criteria is yet available, it is still arguable that the existing beds are not used to their full potential. Additionally, many small plants have an excessive capacity of sand-drying beds for flexibility of operation.

Comparison of Technical Options for Fort Campbell Sludge Dewatering

USACERL considered all sludge dewatering options currently available including land application of sludge at training fields, mechanical dewatering, wedgewater bed, vacuum-assisted beds, reed beds, wedgewater bed dewatering and subsequent composting, and a "no change" option in which sand-drying beds would have been retained. Costs comparison is based on a 7,570 m^3/day (2 MGD) plant, a typical size for an Army WWTP.



A1. Hydraulic loading vs. percent solids



A2. Solids loading vs. percent solids

It was assumed that the 2 MGD plant generates 6,000 gal a day (2.2 million gal per year) of sludge with 5 percent solids content, which is about 1.2 dry tons a day (438 dry tons per year). Assumptions were: an estimation based on a 10-year period, a 10 year lifetime of all facilities, a tipping fee for sludge disposal in KY at $35 per wet ton, $10/ton of transportation cost, and a 3 percent interest rate. A brief summary of the comparison follows:

Land Application of Sludge at Training Field

Without dewatering, sludge can be disposed at the training field rehabilitation area. Sludge generation volume is too small to justify purchase of an expensive sludge transportation truck and feeder and their associated O&M costs.

Mechanical Dewatering

Technical information on the belt filter press, centrifuges, filter press, vacuum filtration, and screw filter was complied through literature search (USEPA 1985; 1987) and contact with vendors. Sharing a mechanical dewatering system on tailor with other Army installation was also considered. Initial costs for mechanical dewatering range from $290,000 to $600,000 (median $445,000) and O&M costs was between $15,000 and $30,000 per year (median $22,500 per year). Expected solid contents vary from 12 to 35 percent (median 23 percent). Generation volume would be 1,904 tons per year.

Wedgewater Beds

USACERL contacted 27 wedgewater bed users (Kim et al. Jan 1992). In most cases, drainage time was under 10 hours, air-drying time was between 3 days and 2 weeks, and target solids contents were between 14 to 20 percent (17 percent). Advantages the users commented included faster turnaround time, lower operating costs and easy maintenance. Users pointed out that solids accumulation underneath the media and labor intensive cleaning requirements were limitations of wedgewater beds.

Two, 24 x 40-ft (total 1,920 sq ft) wedgewater beds were built on one existing sand-drying bed at Fort Campbell. About 65 percent of the sludge, which is produced from about 2 MGD wastewater treatment, is dewatered on these wedgewater beds. Total initial costs were $36,000. The breakdown of these costs were: $5,000 for concrete and side walls, $16,000 for polymer blender and mixer, and $15,000 for front end loader. The annual operational cost was $11,800. This cost includes 4 hours of cleaning for 40 bed use and 4 days

cleaning of underneath media in a year and annual $2,000 polymer cost. Sludge generation volume was 2,190 wet tons.

Vacuum-Assisted Beds

USACERL contacted 28 vacuum-assisted bed (VAB) users (Kim et al. 1992). In comparison with wedgewater beds, VAB's drainage and air drying time could be reduced by applying vacuum underneath the media. However, VAB target solids were about the same as that of wedgewater beds. Users commented that advantages included no weather dependency, fast turnaround time, lower maintenance, and less labor intensive operations than sand beds. Users pointed out tile wear, surface flaking, disintegrating epoxy, and time-consuming cleaning were limitations of VABs. Initially, O&M and disposal costs of the VABs were about same as or slightly higher than those of wedgewater beds.

Reed Bed Dewatering

Of the 24 reed bed users USACERL contacted, all were generally satisfied with their systems. Reed beds offer an economic advantage in that they can be constructed simply by modifying existing sand-drying beds. Based on actual costs for Fort Campbell reed beds, initial costs for 2 MGD plant would be $85,400, O&M cost $6,000 per year. After 10 year's operation, accumulated composted sludge residual will be 9,860 tons (average 986 tons per year). This estimation assumed: a transportation cost of $10/ton, evacuation cost of $10/ton, solid contents of 40 percent, and mineralization of 50 percent volatile solids (10 percent of total dewatered volume) in 10 years. The annualized evacuation cost was $19,720/year.

Wedgewater Bed Dewatering and Subsequent Composting

Annualized composting facility initial costs were $36,800 (Haughney and Vidal 1991) and wedgewater annualized initial costs were $4,212. Haughney and Vidal assumed free bulking agent and revenue of $54,600 from compost sales. In this study, both the cost for bulking agent and revenue from compost sales were ignored.

Sand-Drying Bed, No Change Option

Annual O&M costs and sludge disposal costs for 1,095 wet tons were $21,750 and $48,375 respectively. Assumptions were 750 hours a year labor requirements, $3,000 for sand replacement, and solids content of 40 percent after drying.

Table A1 lists annualized costs, indicating the reed bed (retrofit) as the most economical alternative.

Table A1. Annualized cost comparison of sludge treatment alternatives.

	Initial	O&M	Disposal	Total
Mechanical dewater (new)	52,065	22,500	85,695	160,260
Wedgewater (retrofit)	4,212	11,800	98,550	114,562
Reed bed (retrofit)	9,992	6,000	19,720	35,712
Composting (new)	41,012	26,800	0	67,812
Sand bed (no change)	0	21,750	48,375	70,125

Reed Bed Operational Data

Operational highlights

The Directorate of Public Works at Fort Campbell constructed a 0.9 m high side wall and installed gate valves and sludge distribution pipes before USACERL planted the common reed *Phragmites* with a contract with Sigmatron Corp., NY. In 1994, Fort Campbell raised the side walls from 0.9 to 1.5 m.

In the first and second years, lady bugs were purchased and spread in the beds to eliminate aphids that had infested the young reeds. After the second year, aphid infestation was not evident. Instead of manual harvesting of reeds, reed beds were filled with water to a level 10 cm higher than residue level, and reeds were open burned in a few minutes. In the winter of 1993, reeds were not harvested and naturally decomposed.

Anaerobic sludge of 5 percent solids content was diluted with treatment plant effluent to 3 percent solids content and applied to reed bed about 6 in. deep. In addition to the benefit of better distribution, mixing with high dissolved oxygen water was intended to increase anaerobic sludges' solids loading.

Residual Data

In 1993, a 3-year accumulated residue at the older beds was analyzed. Total residue depth was 71 cm (2.3 ft). Table A2 shows the results of the analysis.

Table A2. Sludge residual column analysis.

Column Depth (cm)	Volatile Solids (percent)	Solids Content (percent)	Fecal Coliform (#/g)	Arsenic (mg/kg)	Copper (mg/kg)	Lead (mg/kg)	
80-10	49	15	4700	<cal	200	27	
10-20	48	21	270	0.31	270	33	
20-30	44	30	19	0.46	370	60	
30-40	45	43	10	0.65	490	110	
40-50	46	40	8	0.86	490	77	
50-71	46	47	103	<cal	630	90	
Column Depth (cm)	**Cadmium (mg/kg)**	**Chromium (mg/kg)**	**Mercury (mg/kg)**	**Molybdenum (mg/kg)**	**Nickel (mg/kg)**	**Selenium (mg/kg)**	**Zinc (mg/kg)**
0-10	<cal	12	1.8	<cal	<cal	<cal	220
10-20	<cal	19	1.9	<cal	8.1	<cal	290
20-30	<cal	24	3.0	<cal	12	<cal	570
30-40	<cal	35	3.8	<cal	20	<cal	540
40-50	<cal	36	5.6	<cal	17	<cal	600
50-71	8.2	48	0.14	<cal	<cal	<cal	<cal

Note: <cal represents a quantity measure below the calibration range

Field observation indicated that the bottom 30 cm of residue consisted of composted brown matter with a fresh smell, owing to the reed's root system, which supplies oxygen to the residue for years. Bottom layers of residues showed sludge was well dewatered (over 40 percent solids). However, the data indicated that volatile solids had not mineralized as expected. About 5 percent volatile solids reduction occurred in 4 years (49 to 46 percent). The metal concentrations are much lower than Part 503 limitation. However, it is interesting that higher metal concentrations were shown at lower (bottom) residue layers. USACERL plans to continue monitoring the reed bed performance.

Sludge residue volume is substantially reduced by combined effects of weathering, micro-organism's biodegradation, thawing and freezing, and reeds' dewatering capability. Newer reed beds in the first 2 years showed less reduction in sludge volume. There appeared to have been less volume reduction at Fort Campbell than at reed beds in Northeastern States. It was postulated that thawing and freezing might play a great role in residue volume reduction. Table A2 also shows that top layer of residue may not meet the pathogen

reduction requirements for the exceptional quality biosolids required by U.S. regulations for beneficial use of biosolids.

Summary of Reed Bed Dewatering

The advantages, limitations, and additional work to be done to effectively use the reed bed technology follow.

Advantages

- *Low investment.* This is especially when a sand-drying beds are converted to reed bed; conversion only requires construction of side wall, reed planting, and installation of a sludge distribution system.

- *No sludge removal costs.* The sludge is treated in reed bed over a period of years. Sludge is well dewatered and mineralized in this time, minimizing sludge volume for disposal. Rather than removing large volume of sludge from sand-drying beds at every dry cycle, small volume of well composted sludge can be removed once in a few years.

- *Simple and economical technology.* Special engineering control, operation and maintenance skill, and additional chemical and energy are not required.

- *Beneficial byproduct.* Sludge residues from the reed bed became well-composted soil after a few years, and can be beneficially used as a soil amendment or landfill cover.

Limitations

- More land area than existing sand-drying beds is required.

- This is an empirical technology. Further science-based research is needed to fine tune this technology.

- A long preparation period (more than a year) is needed before the reed bed is fully operational.

- Volume reduction in warmer climate (e.g., in Kentucky) was smaller than in the colder climate (e.g., in New England). A side wall of 0.9 m was not enough for sludge treatment and storage for many years and was elevated to 1.5 m at Fort Campbell.

Further Work

Since no reed bed has been fully evacuated in the United States, appropriate reed bed evacuation technologies have to be developed. Further research is needed to further reduce pathogen in the top layer of dewatered residue to meet U.S. Beneficial Use of Biosolids regulations. Natural storage of a year without feeding sludge is an option.

Appendix B: USMA West Point Sludge Data

PARAMETERS	Method #	SAMPLE ID (4060.1) USMA West Point Sludge 2	Date Analyzed
pH (Std)	SW 9045C	8.4	8-29-96
TS (%)	EPA 160.3	37.6	8-28-96
TVS (%)	EPA 160.4	65.6	8-28-96
Cadmium	SW 6010A	2.4	8-30-96
Chromium, Total	SW 6010A	16	8-30-96
Copper	SW 6010A	194	8-30-96
Lead	SW 7421	88	8-29-96
Mercury	SW 7471A	<0.3	8-27-96
Nickel	SW 6010A	13	8-30-96
Potassium	SW 6010A	585	8-30-96
Zinc	SW 6010A	400	8-30-96
TKN (wet wt.) *	EPA 351.2	49600	8-30-96
Ammonia (wet wt.)	EPA 350.1	2280	8-30-96
Arsenic	SW 7060A	<8	8-28-96
Nitrite (wet wt. soluble)	EPA 353.1	61	8-27-96
Phosphorus (wet wt.)	EPA 365.4	3640	8-30-96
PCB (total)	SW 8080	<0.5	8-28-96
Molybdenum	SW 6010A	<3	8-29-96

NOTE: All results expressed in mg/kg dry weight unless noted otherwise.

* Subcontracted to ELAP #10233

PARAMETERS	Method #	SAMPLE ID (4041.1) USMA West Point Sludge	Date Analyzed
pH (Std)	SW 9045C	8.5	8-29-96
TS (%)	EPA 160.3	40.0	8-28-96
TVS (%)	EPA 160.4	33.1	8-28-96
Cadmium	SW 6010A	<1.5	8-29-96
Chromium, Total	SW 6010A	12.5	8-29-96
Copper	SW 6010A	135	8-29-96
Lead	SW 7421	44	8-29-96
Mercury	SW 7471A	0.5	8-27-96
Nickel	SW 6010A	10	8-29-96
Potassium	SW 6010A	425	8-29-96
Zinc	SW 6010A	275	8-29-96
TKN (wet wt.) *	EPA 351.2	42800	8-30-96
Ammonia (wet wt.)	EPA 350.1	2320	8-30-96
Arsenic	SW 7060A	<8	8-28-96
Nitrite (wet wt. soluble)	EPA 353.1	1	8-26-96
Phosphorus (wet wt.)	EPA 365.4	5300	8-30-96
PCB (total)	SW 8080	<0.5	8-23-96
Molybdenum	SW 6010A	<3	8-29-96

NOTE: All results expressed in mg/kg dry weight unless noted otherwise.

* Subcontracted to ELAP #10233.

Appendix C: Memorandum From Rockland County Solid Waste Management Authority

ROCKLAND COUNTY
SOLID WASTE MANAGEMENT AUTHORITY
4 Route 340
Orangeburg, New York 10962
(914) 365-6111, (914) 365-6226
Fax. (914) 365-6692

HERBERT REISMAN
Chairman

RONALD C. DELO, P.E.
Executive Director

September 9, 1996

Byung Kim, P.E., Ph.D.
Environmental Engineer
Department of the Army
Construction Engineering Research Laboratories
Corps of Engineers
P.O. Box 9005
Champaign, Illinois 61826-9005

RE: **Sludge from the Target Hill WWTP at West Point Military Academy**

Dear Mr. Kim:

Pursuant to your request for information regarding the feasibility of the Rockland County Solid Waste Management Authority processing the above referenced sludge at its cocomposting facility, please be advised of the following:

1. The Authority will have sufficient capacity to process the sludge from the Target Hill WWTP, estimated to be between 2000-3000 tons per year.

2. A formal request from West Point Military Academy for the Authority to process this sludge would have to be approved by the Authority and would be subject to no objection being received from the Rockland County Legislature within 45 days of their notice of this action from the Authority.

3. The acceptance of this sludge would be subject to receiving a Part 360 Permit Modification from New York State Department of Environmental Conservation for same.

4. Sludge could not begin to be processed at the cocomposting facility prior to January, 1998.

5. The estimated charges for the various sludge processing and transportation options are as follows:

a. Sludge processing with finished compost back hauled in sludge transportation vehicle: **$60/ton**

b. Sludge processing with no finished compost returned to West Point: **$50/ton**

c. Transportation costs utilizing a 20 C.Y. container: **$150/pick up**

The above costs would be adjusted annually based on the Operation Price Index included in the agreement between Waste Management of New York and the Authority.

Should you have any questions on the above, please contact this office.

I look forward to working together with you in providing a beneficial use for West Point sludge.

Very truly yours,

Ronald C. Delo

Ronald C. Delo, P.E.
Executive Director

RCD/rlf

FILE: WEST POINT SLUDGE

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ATTN: CECW-O
ATTN: CECW-P
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ATTN: AETV-WG-AM 09177
293d BSB Unit #29901
ATTN: AEUSG-MA-E 09086
409th Support Battalion (Base)
ATTN: AETTG-DPW 09114
412th Base Support Battalion 09630
ATTN: Unit 31401
221st Base Support Battalion
ATTN: Unit 29623 09096
CMTC Hohenfels 09173
ATTN: AETTH-SB-DPW
Mainz Germany 09185
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21st Support Command
ATTN: DPW (8)
SETAF
ATTN: AESE-EN-D 09613
ATTN: AESE-EN 09630
Supreme Allied Command
ATTN: ACSGEB 09703
ATTN: SHIHB/ENGR 09705

INSCOM
ATTN: IALOG-I 22060
ATTN: IAV-DPW 22186

USA TACOM 48397-5000
ATTN: AMSTA-XE

Defense Distribution Region East
ATTN: ASCE-WI 17070-5001

Defense Distribution Region West
ATTN: ASCW-WG 95296-0100

HQ XVIII Airborne Corps 28307
ATTN: AFZA-DPW-EE

US Army Materiel Command (AMC)
Alexandria, VA 22333-0001
ATTN: AMCEN-F ATTN: AMXEN-C 61299-7190
Installations: (20)

FORSCOM
Forts Gillem & McPherson 30330
ATTN: FCEN
Installations: (20)

TRADOC
Fort Monroe 23651
ATTN: ATBO-G
Installations: (20)

Fort Belvoir 22060
ATTN: CETEC-IM-T
ATTN: CETEC-ES 22315-3803
ATTN: Water Resources Support Ctr

USA Natick RD&E Center 01760
ATTN: STRNC-DT
ATTN: AMSSC-S-IMI

US Army Materials Tech Lab
ATTN: SLCMT-DPW 02172

USARPAC 96858
ATTN: DPW
ATTN: APEN-A

SHAPE 09705
ATTN: Infrastructure Branch LANDA

Area Engineer, AEDC-Area Office
Arnold Air Force Station, TN 37389

HQ USEUCOM 09128
ATTN: ECJ4-EN

CEWES 39180
ATTN: Library

CECRL 03755
ATTN: Library

USA AMCOM
ATTN: Facilities Engr 21719
ATTN: AMSMC-EH 61299
ATTN: Facilities Engr (3) 85613

USAARMC 40121
ATTN: ATZIC-EHA

Military Traffic Mgmt Command
ATTN: MT-LOF 22041-5000
ATTN: MTE-SU-FE 28461

Fort Leonard Wood 65473
ATTN: ATSE-DAC-LB (3)
ATTN: ATZT
ATTN: ATSE-CFLO
ATTN: ATSE-DAC-FL
ATTN: Australian Liaison Office

Military Dist of WASH
Fort McNair
ATTN: ANEN-IS 20319

USA Engr Activity, Capital Area
ATTN: Library 22211

US Army ARDEC 07806-5000
ATTN: AMSTA-AR-IMC

Engr Societies Library
ATTN: Acquisitions 10017

US EPA, Region V
ATTN: AFRC-ENIL-FE 60561

US Army Environmental Center
ATTN: SFIM-AEC-NR 21010
ATTN: SFIM-AEC-CR 64152
ATTN: SFIM-AEC-SR 30335-6801
ATTN: AFIM-AEC-WR 80022-2108

Defense Nuclear Agency
ATTN: NADS 20305

Defense Logistics Agency
ATTN: MMDIS 22060-6221

National Guard Bureau 20310
ATTN: NGB-ARI

US Military Academy 10996
ATTN: MAEN-A
ATTN: Facilities Engineer
ATTN: Geography & Envr Engrg

Naval Facilities Engr Command
ATTN: Facilities Engr Command (8)
ATTN: Engrg Field Divisions (11)
ATTN: Public Works Center (8)
ATTN: Naval Constr Battalion Ctr 93043
ATTN: Naval Facil. Engr. Service Ctr 93043-4328

8th US Army Korea
ATTN: DPW (11)

USA Japan (USARJ)
ATTN: APAJ-EN-ES 96343
ATTN: HONSHU 96343
ATTN: DPW-Okinawa 96376

416th Engineer Command 60623
ATTN: Gibson USAR Ctr

US Army MEDCOM
ATTN: MCFA 78234-6000
Fort Detrick 21702-5000
ATTN: MCHS-IS
Fort Sam Houston 78234-5000
ATTN: MCFA-PW
Walter Reed Army Medical Center 20007-5001
ATTN: MCHL-PW

Tyndall AFB 32403
ATTN: HQAFCESA/CES
ATTN: Engrg & Srvc Lab

USA TSARCOM 63120
ATTN: STSAS-F

American Public Works Assoc. 64104-1806

US Army CHPPM
ATTN: MCHB-DE 21010

West Point U.S. Military Academy 10996
ATTN: MAEN-UFD

US Gov't Printing Office 20401
ATTN: Rec Sec/Deposit Sec (2)

Nat'l Institute of Standards & Tech
ATTN: Library 20899

Defense General Supply Center
ATTN: DGSC-WI 23297-5000

Defense Construction Supply Center
ATTN: DCSC-WI 43216-5000

Defense Tech Info Center 22060-6218
ATTN: DTIC-O (2)

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7/97